MARIA HOLSEN

Operative Treatment and Magnetic Resonance Imaging-Based Diagnostics of Knee Disorders in Military Conscripts

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ABSTRACT

Knee pain is a common complaint among conscripts and physically active young adults in general. Several conditions of the knee can become painful as a result of either increased strenuous activity or blunt trauma to the knee, both abundantly present during the frequent and versatile physical training of compulsory military service. In most conditions causing knee pain, primary treatment is non-operative, but when pain persists operative treatment can provide relief of symptoms. This thesis examines outcome after surgical intervention for osteochondritis dissecans, painful bipartite patella, and medial synovial plica of the knee. Further, the use of magnetic resonance imaging in preoperative diagnostics of medial synovial plicae, and articular cartilage lesions of the patella (also referred to as chondromalacia patellae) is evaluated.

Reattachment of an osteochondritis dissecans fragment of the knee in adults is widely used, but the optimal device for fixation remains controversial and lacking long-term results. In the first study we evaluate the outcome after arthroscopic fixation of the osteochondritis dissecans fragment, using bioabsorbable self-reinforced poly-L-lactide pins and nails, in young adult men performing their compulsory military service. We followed 28 skeletally mature patients (30 knees) for an average of 5.4 years (range 3-12). Patients' mean age at surgery was 20 years (range 19-26). At follow-up functional outcome was evaluated by the Kujala score, and magnetic resonance imaging was used to evaluate subchondral bone healing. Functional results were excellent to good for 73% of the patients in the nail group, compared to 35% in the pin group. The treated lesions were large, with an average size of 447 mm^2, and affected the weightbearing area in the majority of the patients. Magnetic resonance imaging showed incomplete bone consolidation predominantly in the pin group. Arthroscopic fixation with bioabsorbable nails seems to be a suitable method of repair for osteochondritis dissecans of the adult knee, and showed results superior to arthroscopic fixation with bioabsorbable pins.

The purpose of the second study was to evaluate long-term results of excision of a symptomatic accessory bipartite or multipartite patella fragment in young adult men performing their compulsory military service, and to determine the incidence of a painful bipartite patella in this population. We followed 25 skeletally mature

patients for an average of 15 years (range 10-22 years). Median age at surgery was 20 years (range 18-27). The bipartite fragment was superolateral in 19 knees and lateral in 6 knees. Other radiologic findings were rare. The incidence of painful surgically treated bipartite patella was 9.2 per 100,000 conscripts. At follow-up functional results, evaluated by the Kujala score, were excellent to good for 24 patients (96%), and one patient (4%) had a fair functional result. Mild osteoarthritic changes were seen in 2 knees at final follow-up. No reoperation related to bipartite patella had been performed during the follow-up period. We conclude that symptomatic bipartite patella is rare, but when incapacitating pain persists despite nonoperative treatment, surgical excision seems to yield excellent to good functional outcome and swift recovery with no adverse sequelae.

In the third study we evaluate the long-term results of arthroscopic resection of a medial plica, and the usefulness of clinical findings and magnetic resonance imaging for preoperative diagnostics. We followed 25 young adult patients (34 knees) with normal preoperative magnetic resonance imaging of the knee and a sole postoperative diagnosis of medial plica, who had been treated with arthroscopic plica resection. Median age at surgery was 20 years (range 18-28), and the median length of the follow-up was 6.6 years (range 3.6-8.7). Functional outcome at final follow-up was evaluated with the Kujala and Lysholm scores. Results were excellent to good in 68%, fair in 20%, and poor in 12% of the patients. The magnetic resonance imaging classification of the plica size did not show significant correlation with the arthroscopic classification. Resection of the medial plica of a symptomatic knee has good to excellent functional long-term outcome in the majority of cases, and the procedure is not associated with postoperative complications. Magnetic resonance imaging and preoperative clinical examination seem to be unreliable in detecting medial plicae.

The fourth study addressed the applicability of 1.0 Tesla magnetic resonance imaging to diagnosing articular cartilage lesions of the patella, a condition that mostly requires arthroscopy for reliable diagnosis. To evaluate the usefulness of magnetic resonance imaging in avoiding unnecessary arthroscopies we identified 74 consecutive conscripts, performing their compulsory military service, who had preoperative magnetic resonance imaging of the painful knee and a sole diagnosis of articular cartilage lesions of the patella based on arthroscopy. The cartilage lesions seen on arthroscopy were grade I in 27%, grade II in 43%, and grade III in 30% of the cases. Magnetic resonance imaging revealed the cartilage lesion in 49 cases, indicating a sensitivity of 66%, with a 95% confidence interval of 53-74%. Sensitivity increased with the severity of the cartilage lesion, and all grade III

lesions were detected on magnetic resonance imaging. Preoperative clinical symptoms did not correlate with arthroscopic grading of the cartilage lesion. The sensitivity of 1.0 Tesla magnetic resonance imaging for detecting grade I lesions was low and could not be used to confirm a diagnosis of articular cartilage lesions of the patella. Sensitivity was markedly higher for the detection of more severe grade II to III lesions. We conclude that 1.0 Tesla magnetic resonance imaging seems more accurate in detecting severe articular cartilage lesions of the patella.

TIIVISTELMÄ

Polvivaivat ovat yleisiä varusmiehillä, jotka pakollisen asevelvollisuuden vuoksi edustavat kattavasti fyysisesti aktiivista perustervettä nuorta aikuista miesväestöä. Polvi kipeytyy usein lisääntyneen rasituksen tai tylpän polvivamman seurauksena, joille varusmiehet altistuvat varusmiespalvelukseen sisältyvän säännölliseen ja moninaisen fyysiseen harjoittelun myötä. Kipeytymistä selvitettäessä saattaa polvesta löytyä rakenteellinen poikkeama, kuten osteochondritis dissecans, kaksiosainen polvilumpio (bipartite patella), sisäsyrjän nivelkalvon poimu (medial synovial plica) tai polvilumpion rustovaurio. Hoito on kolmella viimeksi mainitulla aikuisväestössä usein alkuun konservatiivista, mutta mikäli konservatiivisella hoidolla ei saavuteta toivottua vastetta, voi vaihtoehtona olla leikkaushoito.

Tämän väitöskirjan tarkoituksena on selvittää polven osteochondritis dissecansin, kivuliaan kaksiosaisen polvilumpion ja mediaalisen nivelkalvopoimun leikkaushoidon pitkäaikaistulokset. Lisäksi selvitämme magneettikuvauksen sensitiivisyyttä mediaalisen nivelkalvopoimun ja polvilumpion rustovaurioiden leikkausta edeltävässä diagnostiikassa.

Polven nivelnastasta irtoavan luurustokappaleen (osteochondritis dissecans) artroskooppinen kiinnitys on aikuisilla yleisesti käytetty hoitomenetelmä, mutta on epäselvää millä kiinnittimillä saavutetaan paras tulos, eikä pitkäaikaisseurannan tuloksia ole. Väitöskirjan ensimmäisenä aineistona oli 28 varusmiestä (30 polvea), joille oli tehty artroskooppinen polven osteochondritis dissecans −kappaleen kiinnitys biohajoavilla sauvoilla tai nastoilla. Potilaiden keski-ikä leikkaushetkellä oli 20 vuotta (vaihteluväli 19−26). Seuranta-aika oli keskimäärin 5,4 vuotta (vaihteluväli 3−12). Toiminnallinen tulos oli lopputarkastuksessa, Kujala −kyselylomaketta käyttäen, erinomainen tai hyvä 73%:lla potilaista, joilla kiinnitys oli tehty biohajoavilla nauloilla ja 35%:lla potilaista joille kiinnitys oli tehty biohajoavilla sauvoilla. Kiinnitetyt kappaleet olivat laajoja, keskimäärin 447 mm², ja sijaitsivat pääosalla potilaista kantavalla nivelpinnalla. Magneettikuvauksessa nähtiin kiinnitetyn kappaleen puutteellista luutumista pääasiassa sauva ryhmässä. Osteochondritis dissecans kappaleen artroskooppinen kiinnittäminen biohajoavilla nauloilla vaikuttaa olevan hyvä aikuisen polven osteochondritis dissecansin

hoitomenetelmänä ja tuotti paremman tuloksen kuin kiinnittäminen biohajoavilla sauvoilla.

Kivuliaan kaksiosaisen polvilumpion tavallisin leikkauksellinen hoitomenetelmä on polvilumpion pienemmän kappaleen poisto, mutta pitkäaikaistuloksia on niukasti. Toisessa osatyössä aineistona oli 25 varusmiestä, joille oli tehty kivuliaan kaksiosaisen polvilumpion pienemmän kappaleen poisto. Potilaiden mediaani-ikä leikkaushetkellä oli 20 vuotta (vaihteluväli 18–27). Poistettava kappale sijaitsi 19 polvessa superolateraalisesti ja 6 polvessa lateraalisesti. Muita poikkeavia radiologisia löydöksiä oli vähän. Määritimme myös esiintyvyyden; 9,2 kivuliasta leikkauksella hoidettua kaksiosaista polvilumpiota 100 000 varusmiestä kohti. Keskimääräinen seuranta-aika oli 15 vuotta (vaihteluväli 10–22), ja sen loppuessa oli toiminnallinen tulos, Kujala asteikolla arvioituna, erinomainen tai hyvä 96%:lla ja kohtalainen 4%:lla potilaista. Lievää nivelrikkoa nähtiin lopputarkastuksessa kahdessa polvessa. Uusintaleikkauksia kaksiosaisen polvilumpion takia ei oltu seuranta-aikana tehty. Kivulias kaksiosainen polvilumpio on harvinainen, mutta vaikuttaa siltä, että pitkittyneessä kipuilussa pienemmän kappaleen poistolla saavutetaan erinomainen tai hyvä toiminallinen lopputulos ja nopea toipuminen ilman epätoivottuja jälkivaikutuksia.

Kolmannessa osatyössä tutkimme polven mediaalisen nivelkalvopoimun artroskooppisen poiston pitkäaikaistuloksia sekä kliinisten oireiden ja magneettikuvauksen hyödyllisyyttä leikkausta edeltävässä diagnostiikassa. Aineistoon valikoitui 25 varusmiestä (34 polvea), joilla oli leikkausta edeltävästi magneettikuvauksessa normaali löydös ja artroskooppisesti poistettu nivelkalvon poimu, joka oli myös ainoa diagnoosi. Potilaiden mediaani-ikä leikkaushetkellä oli 20 vuotta (vaihteluväli 18–28), ja seuranta-ajan mediaani oli 6,6 vuotta (vaihteluväli 3,6–8,7). Toiminnallinen tulos oli, Kujala ja Lysholm -asteikoilla mitattuna, seuranta-ajan loppuessa erinomainen tai hyvä 68%:lla, kohtalainen 20%:lla ja välttävä 12%:lla potilaista. Magneettikuvauksen perusteella tehdyn nivelkalvopoimun kokoluokituksen ja artroskopiassa tehdyn kokoluokituksen välillä ei ollut merkittävää korrelaatiota. Oireisen polven nivelkalvopoimun artroskooppisen poiston jälkeen toiminnallinen pitkäaikaistulos oli pääosalla potilasta erinomainen tai hyvä, eikä toimenpiteeseen liittynyt komplikaatioita. Magneettikuvaus ja leikkausta edeltävä kliininen tutkimus eivät vaikuta luotettavasti löytävän polven sisäsyrjän nivelkalvon poimua.

Polvilumpion rustovaurion luotettava diagnoosi perustuu usein artroskopiaan. Leikkaushoito ei kuitenkaan yleensä ole polvilumpion rustovauriossa tarpeen ja turhia artroskopioita tulisi välttää. Neljännessä osatyössä selvitimme 1.0 Tesla

magneettikuvauksen käyttökelpoisuutta polvilumpion rustovaurioiden diagnostiikassa. Aineistoon valikoitui 74 varusmiestä, joille oli tehty leikkausta edeltävä magneettikuvaus ja joilla artroskopiassa ainoana diagnoosina oli polvilumpion rustovaurio. Artroskopiassa todetuista rustovaurioista 27% oli luokkaa I, 43% oli luokkaa II ja 30% oli luokkaa III. Magneettikuvaus löysi näistä 49, eli magneettikuvauksen herkkyys oli 66% (95% luottamusväli: 53−74%). Magneettikuvauksen herkkyys lisääntyi rustovaurion syvyyden myötä ja kaikki luokkaa III olevat rustovauriot todettiin magneettikuvauksessa. Leikkausta edeltävät kliiniset oireet ja rustovaurioiden artroskooppinen luokitus eivät korreloineet keskenään. Magneettikuvauksen herkkyys oli heikko luokan I rustovaurioiden osalta, eikä soveltunut vahvistamaan polvilumpion rustovauriodiagnoosia. Herkkyys oli huomattavasti parempi syvempien, luokkaa II−III, rustovaurioiden todentamisessa. Magneettikuvausta (1.0 Tesla) voidaan tämän perusteella pitää luotettavana diagnostisena apuvälineenä polvilumpion syvempien rustovaurioiden todentamisessa.

TABLE OF CONTENTS

LIST OF ORIGINAL PUBLICATIONS

This thesis is based on the following original publications, which are referred to in the text by the Roman numerals I-IV:

I   Weckström M, Parviainen M, Kiuru MJ, Mattila VM, Pihlajamäki HK. Comparison of bioabsorbable pins and nails in the fixation of adult osteochondritis dissecans fragments of the knee: an outcome of 30 knees. Am J Sports Med. 2007;35(9), 1467-1476.

II   Weckström M, Parvianen M, Pihlajamäki HK. Excision of painful bipartite patella: good long-term outcome in young adults. Clin Orthop Relat Res. 2008;446(11), 2848-2855.

III   Weckström M, Niva MH, Lamminen A, MattilaVM, Pihlajamäki HK. Arthroscopic resection of medial plica of the knee in young adults. Knee. 2010;17(2), 1003-1007.

IV   Mattila VM, Weckström M, Leppänen V, Kiuru M, Pihlajamäki H. Sensitivity of MRI for articular cartilage lesions of the patellae. Scand J Surg. 2012;101(1), 56-61.

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Maria Holsen née Weckström

1 INTRODUCTION

Anterior knee pain (AKP) is a common knee complaint, particularly in the young and active population (Samim et al. 2014, Kang et al. 2016). Reportedly up to 30% of all visits to sports medicine practitioners are for anterior knee pain, and the incidence of anterior knee pain in young athletes is assumed to be around 10% (Houghton 2007). Anterior knee pain is considered to be more common among females, but frequent occurrence has also been reported in male soldiers during military service (Lakstein et al. 2010, Kang et al. 2016). The etiology is not clear, but several conditions are thought to be possible causes of anterior knee pain (Houghton 2007). Most cases improve with non-surgical treatment (Crossley et al. 2016), but individual management based on the major cause of anterior knee pain has been recommended for persevering pain, not responding to conservative treatment (Kang et al. 2016). The four conditions assessed in this thesis; osteochondritis dissecans (OCD) of the knee, bipartite patella, medial synovial plica and articular cartilage lesions of the patella (often referred to as chondromalacia patellae), are considered to be rare but possible causes for anterior knee pain (Houghton 2007, Kang et al. 2016).

The study population of this thesis comprises young adults who perform combat training, marching, and other physical training activities almost daily throughout their military service period. Knee pain is common in this group of physically active young men, and may markedly interfere with their performance of military training, even to the extent of threatening the completion of military service.

Osteochondritis dissecans of the knee is a focal, idiopathic alteration of subchondral bone with potential for instability or fracture of overlying cartilage, which may result in premature arthrosis (Edmonds and Polousky 2013, Carey et al. 2016). When left untreated a fragment of articular cartilage, with or without underlying subchondral bone, may eventually split off from the condylus, most frequently from the medial condyle (Obedian and Grelsamer 1997). More or less attached fragments, or even loose bodies, can be reattached using bioabsorbable (Böstman 1991, Rokkanen et al. 2000, Yonetani et al. 2010, Wouters et al. 2011, Chun et al. 2016) or other (Lindholm et al. 1977, Thomson 1987, Mackie et al.

1990, Slough et al. 1991, Victoroff et al. 1996, Makino et al. 2005) implants. Studies reporting long-term results of reattachment are sparse, and no agreement has been reached on the most profitable method of fixation (Erickson et al. 2013, Winthrop et al. 2015). While the aim of reattachment is to preserve an even chondral surface and thereby restore function and prevent or delay development or progression of secondary arthrosis (Smillie 1957, Linden 1977), we lack knowledge of to what extent operative treatment of osteochondritis dissecans can in fact delay or even prevent progression of the condition. In preoperative evaluation of lesion characteristics magnetic resonance imaging (MRI) has been successfully used to complement plain radiographs, but it remains unclear how accurately magnetic resonance imaging can determine instability and prognosis, especially in adolescents.

The bipartite patella is a patella composed of two parts, separated by fibrocartilage (O'Brien et al. 2011), that develops due to a failure of accessory ossification centers to fuse to the main patella during adolescence (Gruber 1883, Adams and Leonard 1925, George 1935, Oohashi et al. 2006, Samim et al. 2014). The most prevalent location for the accessory fragment, formed by this aberration, is the superolateral part of the patella (Matic and Flanigan 2015). The condition is often an incidental finding without clinical significance (Weaver 1977, Iossifidis and Brueton 1995, Samim et al. 2014, Oohashi 2015), but symptoms have been seen to arise after overuse or direct trauma to the knee (Ogden et al. 1982, Smillie 1962, Oohashi 2015). While a painful bipartite patella is initially treated with short immobilization and other necessary conservative methods, operative treatment may be considered when pain persists despite conservative treatment (Weaver 1977, Iossifidis and Brueton 1995, Samim et al. 2014). The most common operative method remains the removal of the smaller fragment of the patella (Mori et al. 1995, Adachi et al. 2002, Azarbod et al. 2005), either through a small opening or arthroscopically. Both approaches have produced good to excellent results in shorter follow-up (Matic and Flanigan 2014), but reports on long-term follow-up for skeletally mature patients are lacking. It remains to be seen whether a predisposition to premature osteoarthritis as a result of treatment will be seen, and whether the choice of treatment method would correlate with this.

Sometimes the only finding in a knee with prolonged pain is a synovial fold called a plica. The plica is a normal anatomical structure found in around 80% of the population (Kent and Khanduja 2010, Kramer et al. 2016) and in most cases asymptomatic and clinically irrelevant. A plical structure can be found in the superior, inferior, lateral or medial part of the knee cavity, but it is the medial plica

which most frequently becomes symptomatic (Samim et al. 2014, Vassiou et al. 2015). The shape varies from a slight bulge of synovial lining to a shelf-like protrusion of varying size and consistency (Sakakibara 1976, Boven et al. 1983, Kim and Choe 1997, Lyu and Hsu 2006). While the synovial plica was first described in the beginning of last century (Dupont 1997), its role in causing symptoms is still debated (Schindler 2014, Stubbings and Smith 2014, Vassiou et al. 2015) and its pathophysiology not completely understood. A blunt trauma of the knee or repetitive flexion extension activity often precedes onset of symptoms that have been attributed to a medial plica (Hardaker et al. 1980, Hansen and Boe 1989, Dorchak et al. 1991), but other intra-articular pathology may also trigger irritation of the plica causing it to become thicker and less pliable with a potential risk of bruising the chondral surface of either the medial condyle or the medial facet of the patella (Patel 1978, Lyu and Hsu 2006). Whether the main reason of plica symptoms lies in a change of consistency and mechanical friction, or in fact within the realm of tissue homeostasis and increase of nerve endings (Irha and Vrdoljak 2003, Farkas et al. 2004, Dye 2005), needs further exploring. The decision to resect a plica has to be made based on both the presentation of symptoms and the size and consistency of the plica. Although total or subtotal resection of a plica thought to be symptomatic and persistent to conservative treatment, has been practised for several decades (Vaughan-Lane and Dandy 1982, Nottage et al. 1983, Maffulli et al. 1993, Flanagan et al. 1994, Kan et al. 2015), we lack studies with long-term follow-up results. While a plica is well visible on arthroscopy, efforts have been made to improve the accuracy of preoperative and less invasive diagnostics. One would assume that the benefits of magnetic resonance imaging could be applicable to plica diagnostics as well, but in light of reported results the relevance of magnetic resonance imaging, in terms of plica diagnostics, still seems somewhat vague (Garcia-Valtuille et al. 2002, Boles et al. 2004, Uysal et al. 2008, Vassiou et al. 2015).

The association between clinical symptoms and the presence of softened articular cartilage is controversial (Leslie and Bentley 1978, Dye 2005, Llopis and Padron 2007, Teitge 2008, Wittstein et al. 2009). Articular cartilage lesions of the patellae, previously referred to as chondromalacia patellae, are a very common finding in military conscripts with knee complaints. Distinguishing actual articular cartilage lesions of the patellae from other causes of knee pain is difficult based on physical examination alone, and articular cartilage lesions of the patellae cannot be seen on radiographs until advanced stages (Pihlajamäki et al. 2010). Magnetic resonance imaging has proven to be a valuable and useful tool in assessing

chondral lesions of the patella (Kang et al. 2016). Despite improved imaging of the knee, arthroscopy is still considered gold standard when it comes to diagnosing patellar articular cartilage lesions (Macmull et al. 2012, Smith et al. 2012, Duran et al. 2016). In most cases operative treatment is not necessary (Dehaven et al. 1979, Kruger et al. 2000, Duran et al. 2016) and initiative treatment comprises conservative rehabilitation (Shahriaree 1985, Werner 2014, Crossley et al. 2016). Arthroscopy for shaving or removing fibrillated and traumatized areas of articular cartilage has been used for deeper patellar lesions, despite evidence that positive outcome may deteriorate over time (Shahriaree 1985, Federico and Reider 1997, Macmull et al. 2012), and there would seem to be a slight decrease in knee arthroscopies performed in this age group in recent time (Bohensky et al. 2012, Harris et al. 2013). If arthroscopic examination does not reveal a need for operative treatment, it is a costly and invasive diagnostic method and unnecessarily binds restricted healthcare resources. Improved knowledge of articular cartilage lesions of the patella, and their appearance on magnetic resonance imaging, may allow for improved treatment and avoidance of diagnostic arthroscopies.

This study was initiated to evaluate operative treatment and magnetic resonance imaging diagnostics of the four mentioned conditions, repeatedly encountered in military conscripts with knee symptoms. The first study evaluates the outcome of reattachment of an osteochondritis dissecans fragment with bioabsorbable implants, with categorical use of magnetic resonance imaging as part of the evaluation process. The second study assesses long-term outcome of excision of a bipartite patellar fragment. The third study evaluates the long term outcome of arthroscopic plica resection and the use of magnetic resonance imaging in plica diagnostics. In the fourth study we assess the sensitivity of magnetic resonance imaging in detecting articular cartilage lesions of the patella.

2 REVIEW OF LITERATURE

The goal of treatment for knee disorders like osteochondritis dissecans, bipartite patella, medial synovial plica and patellar chondral lesions is relieving symptoms and restoring normal function and movement. On longer term striving to restore joint anatomy and function would seem beneficial in preventing premature degeneration of the knee joint (Jones and Williams 2016), although there is a lack of long-term follow-up to support this presumption.

2.1 Osteochondritis dissecans

Osteochondritis dissecans was first described in 1870 by Paget, who called it "quiet necrosis" (Paget 1870). König some years later named it osteochondritis dissecans (König 1887, Barrie 1987), where "dissecans" describes the cutting loose of the lesion (Herring 2002). Osteochondritis dissecans can be found in any joint, but it typically affects the knee (Obedian and Grelsamer 1997). In its less severe forms no changes are seen on the articular surface while visible on plain radiographs or magnetic resonance imaging (Carey et al. 2016). As the condition progresses demarcation becomes visible around its borders and, if left untreated, breakage of cartilage may occur along these demarcation lines and, as end point, eventually complete detachment of the fragment may occur. The defect this leaves in the articular chondral surface would seem prone to early osteoarthritic changes (Herring 2002, Edmonds and Polousky 2013).

Figure 1. Osteochondritis dissecans located in the medial condyle of the left knee. Reprinted from original publication I (Weckström et al. 2006) with permission of SAGE Publications.

The size of an osteochondritis dissecans fragment varies, but is generally about 3.3 cm² (Abouassaly et al. 2014). It is often located on the weightbearing area of the medial condyle of the knee. More rarely, in less than one out of five cases, it is seen on the lateral condyle (Edmonds and Polousky 2013). Due to its location and characteristics it is prone to cause pain in activity, and depending on location and degree of detachment it might also cause mechanical symptoms.

Osteochondritis dissecans has an annual incidence of 15 to 29 per 100 000 population (Camp et al. 2013) and it is a condition found predominantly in males, both adolescent and young adults (Jones and Williams 2016). Bilateral findings are seen in about 30% (Obedian and Grelsamer 1997, Pascual-Garrido et al. 2009). Athletes are well represented (Shea et al. 2013, Edmonds and Polousky 2013), as well as military conscripts, both of which have more strain and possible traumas to the knee than the population in general. This has prompted a theory of trauma and overuse being significant in development of symptomatic osteochondritis dissecans. Other causes that have been considered include genetic predisposition, abnormal ossification, endocrine abnormalities and ischemia (Obedian and Grelsamer 1997, Cain et al. 2001, Shea et al. 2013). Less significance is today put on inflammatory factors, which were originally assumed to be causing the condition, hence the name osteochondritis. There is no absolute consensus as to

etiology, but it is largely considered multifactorial (Shea et al. 2013, Erickson et al. 2013).

The diagnosis of osteochondritis dissecans is made based on plain radiographs or magnetic resonance imaging (Herring 2002, Jones and Williams 2016). Clinical presentation includes pain aggravated by activity, possible effusion, and at times mechanical symptoms, such as locking or snapping. In prolonged, untreated cases atrophy of the thigh has been observed (Erickson et al. 2013). The Aichroth and Harding classifications (Aichroth 1971, Harding 1977) are used to describe the location on radiographs, and the arthroscopic Guhl classification (Guhl 1982) to describe the condition of the lesion. A recent addition to classification systems is an arthroscopical classification, developed by the multi-center study group Research in OsteoChondritis of the Knee (ROCK), designed with the aspiration to gain a more comprehensive description of the condition of the lesion (Carey et al. 2016).

The ROCK OCD knee arthroscopy classification system

Immobile lesions	Cue ball	No abnormality detectable arthroscopically
	Shadow	Cartilage is intact and subtly demarcated (possibly under low light)
	Wrinkle in the rug	Cartilage is demarcated with a fissure, buckle, and/or wrinkle
Mobile lesions	Locked door	Cartilage fissuring at perifery, <u>unable</u> to hinge open.
	Trap door	Cartilage fissuring at periphery, <u>able</u> to hinge open
	Crater	Exposed subchondral bone defect

Table 1. The ROCK OCD knee arthroscopy classification system (Carey et al. 2016).

The aim of surgical intervention is to restore or preserve an intact articular chondral surface. There is a wide array of treatment options that strive to do this. In choosing a suitable treatment method both patient related and lesion related factors need to be taken into account. Patient related factors are age, skeletal maturity and patient's activity level. Skeletal immaturity implies better potential for spontaneous healing, and good response to both conservative and surgical treatment methods (Green 1966, Jones and Williams 2016). The skeletally mature patients usually respond poorly to conservative treatment and tend to require surgical treatment for a symptomatic condition (Garrett 1991, Winthrop et al. 2015). Lesion related factors are fragment size, location, and presence and condition of subchondral bone on the fragment (Erickson et al. 2013).

Surgical management of osteochondritis dissecans of the knee

Palliative	Loose body removal
	Chondroplasty/debridement
Reparative	Arthroscopic / Open Reduction and Internal Fixation (ARIF/ORIF)
	Drilling; transarticular or retroarticular
Reconstructive	Osteochondral Autograft Transplant System (OATS)
	Osteochondral allografting
Restorative	Autologous chondrocyte implantation (ACI)
	Biomimetic scaffolds
	Bone cartilage paste grafting
	Microfracture

Table 2. Different surgical techniques for management of osteochondritis dissecans of the knee

Reparative techniques strive to repair or preserve the articular chondral surface by reattaching the fragment. A largely used reparative method is arthroscopic reattachment of the fragment. This can be achieved using a variety of fixation devices or implants, made either of metal or bioabsorbable materials. Metal cannulated screws, compression screws and Herbert screws offer good rigidity to the fraction site (Thomson 1987, Mackie et al. 1990, Makino et al. 2005, Anderson et al. 2013), but usually require a subsequent procedure for removal. Bioabsorbable implants have been used for fracture fixation since 1984 (Böstman 1991, Rokkanen et al. 2000) and have the benefits of not requiring subsequent removal and of gradual shifting stress to the fracture site (Dervin et al. 1998). Bioabsorbable implants that have been used for osteochondritis dissecans fixation include pins (Matsusue et al. 1996, Tuompo et al. 1997, Dervin et al. 1998, Nakagawa et al. 2002), nails (Din et al. 2006, Abouassaly et al. 2014), compression and lag screws (Camp et al. 2013, Abouassaly et al. 2014) and menicus arrows (Wouters et al. 2011). Intra-articular use of bioabsorbable devices has been regarded with some suspicion because of reports of post-operative synovitis (Barfod and Svendsen 1992, Friden and Rydholm 1992) and implant breakage (Friederichs et al. 2001, Millington et al. 2010) or loosening (Scioscia et al. 2001) causing chondral damage. Experimental animal studies nevertheless show no significant difference in biocompatibility between bioabsorbable poly-L-lactide and metallic devices in short and long-term follow-up when the implant was placed in cancellous bone (Pihlajamäki, Böstman et al. 2006, Pihlajamäki, Salminen et al. 2006). The majority of studies of osteochondritis dissecans fixation with bioabsorbable devices report rare (Tuompo et al. 1997, Dervin et al. 1998) or no (Matsusue et al. 1996, Nakagawa et al. 2002, Larsen et al. 2005, Yonetani et al. 2010) cases of synovitis, implant breakage or chondral damage, and significant differences have not been seen broad scale between different material implants as to results (Pascual-Garrido et al. 2009). A recent review states that fixation with bioabsorbable implants is the most common choice in treating unstable osteochondritis dissecans in skeletally immature patients (Abouassaly et al. 2014).

Other surgical options in treatment of osteochondritis dissecans include removal of loose bodies, drilling of subchondral bone to improve vascularity (Green 1966, Jones and Williams 2016), and varied reconstructive osteochondral techniques.

Removal of loose bodies or debridement of the chondral defect is performed in order to relieve mechanical symptoms, but without restoring the chondral surface (Winthrop et al. 2015). While symptoms can be eliminated the removal of loose

bodies has little or no favourable influence on long-term functionality. This type of intervention removes the cause of pain, but leaves the articular chondral defect unchanged, thus being potentially prone to early secondary arthrosis (Edmonds and Polousky 2013, Jones and Williams 2016).

Drilling through both fragment and lesion site is performed to prevent loosening of a stable lesion in skeletally immature patients. This results in migration of inflammatory factors and stem cells into the interface and is thought to thus enhance ossification (Edmonds and Polousky 2013) in the skeletally immature knee, but has little effect in skeletally mature knees.

Different reconstructive or restorative methods can be used in cases where reattachment is not possible or lesions are large (Yamashita et al. 1985, Homminga et al. 1990, Outerbridge et al. 1995, Angermann et al. 1998, Bakay et al. 1998, Berlet et al. 1999, Nakagawa et al. 2002, DiBartola et al. 2016). These include autologous chondrocyte implantation (ACI), osteochondral autograft transplant (OATS), osteochondral allografting, bone-cartilage paste graft and biomimetic osteochondral scaffolds (Kon et al. 2012, Winthrop et al. 2015). When comparing OATS (removing osteochondral plugs from the margins of the articular chondral surface and planting them at the defect site), with ACI (cultivating chondrocytes from the patient's knee in vitro and implanting these at the defect site covered with a membrane), DiBartola et al. found that OATS repairs were more likely to comprise of hyaline cartilage, but repairs from chondrocyte implantation became more hyaline like over time (DiBartola et al. 2016). Refixation is nevertheless recommended, when possible, as first line procedure for adult osteochondritis dissecans, as it shows better results than cartilage reconstructive or restorative measures (Pascual-Garrido et al. 2009, Jones and Williams 2016).

2.2 Bipartite patella

The largest sesamoid bone in the body, the patella, ossifies initially between 3-5 years of age (Oohashi et al. 2010). As the ossification center enlarges, the expanding margins become irregular and associated with accessory ossification centers most commonly in the superolateral region (Herring 2002, Oohashi et al. 2010). The accessory ossification occurs around 12 years of age and accessory ossification centers generally fuse during adolescence (O'Brien et al. 2011). The bipartite patella arises when a secondary ossification center fails to coalesce to the main part of the patella (Gruber 1883, Adams 1925, George 1935, Oohashi et al.

2006). More than one accessory center may fail to fuse resulting in multipartite patella, a condition more rare than the bipartite. The aberration in ossification results in a synchondrosis between the main part of the patella and the accessory fragment, i.e. the fragment remains separated from the patella by fibrocartilage (O'Brien et al. 2011). This has recently also been referred to as developmental anomaly of ossification type patella partita (Oohashi 2015), a term applicable to both bipartite and multipartite patellae. Other reasons for the formation of this chondroosseous disruption of the patella that have been presented, include trauma and nonunion (Devas 1960, Smillie 1962), tendinous traction (Todd and McCally 1921, Smillie 1962, van Holsbeeck et al. 1987, Ogata 1994), vascular insufficiency (Smillie 1962), or a combination of these (Bourne and Bianco 1990).

Figure 2. Superolateral fragment of a bipartite patella (arrow). Reprinted from original publication II (Weckström et al. 2008), with permission of Springer.

The accessory fragment usually has a diameter of less than 2 cm (O'Brien et al. 2011), but larger fragments have been reported as well (Vaishya et al. 2015). The width of the diastasis between an asymptomatic fragment and patella tends to be less than 2 mm, and the articular cartilage of the fragment tends to be thinner than the articular cartilage of the main part of the patella (O'Brien et al. 2011).

Prevalence of bipartite or multipartite patella is reported to be around 0.2% to 6% in the adult population (Todd and McCally 1921, Green 1975, Kavanagh et al.

2007, O'Brien et al. 2011) and it is important to distinguish bipartite patella from a patellar fracture (Oohashi and Oohashi 2011). Most bipartite patellae are asymptomatic (Weaver 1977, O'Brien et al. 2011) and a clinically insignificant anatomic variant (Todd and McCally 1921, Green 1975, Kavanagh et al. 2007, Oohashi 2015). When, in less than 2% (Weaver 1977, Oohashi 2015), the bipartite patella does become painful, it is usually either with a gradual onset due to overuse and continuous strenuous exercise, typically seen in athletes (Weaver 1977) and soldiers (Todd and McCally 1921), or with a more sudden onset after trauma (Todd and McCally 1921, Smillie 1962, Ogden et al. 1982, Oohashi 2015, Matic and Flanigan 2015). In the age group of adolescents and young adults mobility of the fragment during strenuous activity is assumed to be the most common cause of pain, whereas in adults a bipartite patella can become painful after minor or major injury with possible acute separation of the fragment (Oohashi et al. 2010). Commonly symptoms occur in adolescent or young adult males (Oohashi et al. 2010, O'Brien et al. 2011, Matic and Flanigan 2015), although no anatomic or other reason has been noted in these reports to explain male dominance (Weaver 1977, Bourne and Bianco 1990, Ogata 1994, Mori et al. 1995, Adachi et al. 2002). The condition is reportedly bilateral in 25% to 56% (Green 1975, Canizares and Selesnick 2003, Oohashi et al. 2010, O'Brien et al. 2011), and the proportion of bilaterality tends to be smaller when symptoms arise after trauma (Tietjens et al. 1992).

Figure 3.   The bipartite patella with an inferior (I), lateral(II) or superolateral(III) accessory fragment as classified by Saupe (Saupe 1921).

Bipartite patellae are classified according to location into three groups (Figure 3); type I involving the inferior pole (5%), type II the lateral margin (20%) and type III the superolateral quadrant (75%) of the patella (Saupe 1921, O'Brien et al. 2011). There is, however, some debate on whether an inferior pole bipartite patella (type I) exists, or is in fact rather Sinding-Larsen-Johansson syndrome, spastic

cerebral palsy related or a fracture or stress fracture (Oohashi et al. 2010, Oohashi and Oohashi 2011). Consequentially a new classification has fairly recently been introduced (Figure 4), which leaves out type I (inferior pole) and instead includes two tripartite classes; a superolateral and a superolateral-lateral (Oohashi et al. 2010). It remains to be seen if this classification will find its way to clinicians, considering its slightly more complicated nature.

Figure 4. Oohashi classification of the partite patella; the supero-lateral bipartite type, the lateral bipartite type, the supero-lateral and lateral tripartite type, the supero-lateral tripartite type (Oohashi et al. 2010).

The well corticated accessory bipartite patellar fragment is well visible on plain radiographs, and a possible separation of fragments can be visualized as well (Herring 2002). Magnetic resonance imaging is occasionally used to gain additional knowledge, and it helps differential diagnosis if e.g. a fracture cannot be ruled out based on the medical history (O'Brien et al. 2011). It has also been advocated for detecting mobility at the interface, demonstrated by a fluid bright signal across the segmentation (Oohashi 2015).

A painful bipartite patella is primarily treated with conservative measures; restriction of activities or temporary immobilization (Herring 2002, Matic and Flanigan 2015), which relieve symptoms in most cases. Nonoperative treatment is preferred, especially for adolescent patients and patients with a more gradual onset of symptoms (Ogden et al. 1982). When symptoms persist surgical measures provide good relief from symptoms, even after duration of symptoms of up to 11 years (Iossifidis and Brueton 1995). The most widely used surgical method is excision of the, usually superolateral, accessory fragment (Mori et al. 1995, Adachi et al. 2002, Azarbod et al. 2005), and it is reported to have the best outcome in returning athletes to their prior activity level (Matic and Flanigan 2015). The removal of the accessory fragment is usually performed through a small incision over the area in question, but arthroscopic excisions have been reported as well. Open and arthroscopic excisions have equally good reported results in a recent

review, with 98% of the patients painless and returning to the same level of sports (Matic and Flanigan 2014). As benefits of an arthroscopic procedure may include a faster recovery time with less postoperative knee effusion, allowing for more aggressive rehabilitation and reduction in quadriceps weakness (Felli et al. 2011, Matic and Flanigan 2014), it remains to be seen if an increase in the 6% arthroscopic excisions (Matic and Flanigan 2014) might be seen over time.

Other surgical options for painful bipartite patella include the soft tissue procedures vastus lateralis release and lateral retinacular release (Ogata 1994, Mori et al. 1995, Adachi et al. 2002), and on the other hand open reduction and internal fixation of the fragment in cases with acute painful separation or a large fragment (Ishikawa et al. 1994, Canizares and Seselnick 2003, Vaishya et al. 2015).

Soft tissue procedures are used in treatment of painful bipartite patella, with or without excision, to reduce the traction these tissues exercise on the fragment and thus relieve the pain that is assumed to arise from mobility at the fibrocartilagenous interface between the patella and the accessory fragment (O'Brien et al. 2011). Results for a sole vastus lateralis release, the less invasive of the two, do not seem outstanding when it comes to bony union. Lateral retinacular release appears to achieve better numbers in terms of bony union, but neither would appear to obtain as good results as excision in terms of relief of pain, with 31% and 21% suffering from persisting pain after lateral retinacular release and vastus lateralis release respectively (Ogata 1994, Mori et al. 1995, Adachi et al. 2002).

In cases of bipartite patella with an acute separation of the fragment, or in cases with large (> 2 cm) accessory fragments, open reduction and internal fixation has been used as a treatment method (Vaishya et al. 2015). Open reduction and internal fixation is an invasive intervention, with a post-operative rehabilitation much longer and more extensive than in the other procedures mentioned (Oohashi 2015). It could be argued that the risk for secondary arthrosis might be diminished by such a procedure, but in cases with severe cartilage lesions the fragment should be excised regardless of size (Vaishya et al. 2015).

2.3   Medial synovial plica

The medial plica is a synovial fold, a normal anatomic structure of the knee, that courses from the superior parts of the medial wall obliquely down to the synovial lining of the infrapatellar fat pad. It is usually a transparent, thin and pliable structure and as such is not considered clinically relevant. A medial plica is a

common finding in knee arthroscopies, especially in the age range of 11 to 40 years (Sakakibara 1976, Boven et al. 1983, Kim and Choe 1997, Christoforakis et al. 2006, Lyu and Hsu 2006, Guney et al. 2010), and has an incidence of reportedly up to 80% (Al-Hadithy et al. 2011, Schindler 2014). Most reports show a fairly even distribution between men and women (Hansen and Boe 1989, Johnson et al. 1993, Flanagan et al. 1994, Schindler 2014), while others report female dominance (Vaughan-Lane and Dandy 1982, Kan et al. 2015, Kramer et al. 2016).
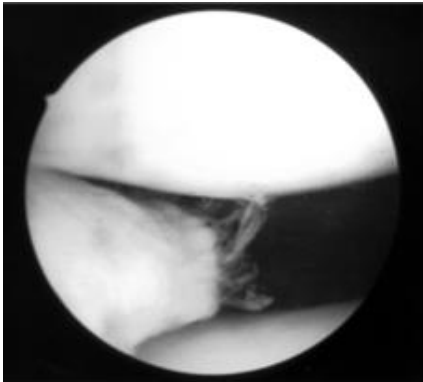

Figure 5. Large shelf-like medial plica on intraoperative arthroscopic photograph prior to resection. Reprinted from original publication III (Weckström et al. 2010) with permission of Elsevier.

A normal plica consists of a lining of single or reduplicated synovial cells resting on a stroma of connective tissue with abundant small blood vessels and collagen fibres (Schindler 2014). A commonly presented assumption is that direct trauma to the knee or repetitive indirect trauma of continuous strenuous exercise (Hardaker et al. 1980, Hansen and Boe 1989, Dorchak et al. 1991) may provoke inflammation in the synovial tissue of the plica, leading to thickening and oedema of the plical fold and, if persistent, may precipitate the replacement of elastic tissue with fibrous elements. Factors, other than trauma, that are thought to trigger an inflammatory reaction in the plical structure include surgical interventions or intra-articular derangements such as torn menisci, loose bodies, osteochondritis dissecans or patellar subluxation (Schindler 2014). Owing to the anatomic location of the medial plica, a loss of normal elasticity can cause it to impinge on the femoral medial condyle or the medial facet of the patella during flexion-extension motion of the knee (Patel 1978, Lyu and Hsu 2006, Guney et al. 2010, Schindler 2014, Kan et al. 2015). This kind of repetitive contact may result in a chondral lesion of varying severity, sometimes referred to as an impingement lesion (Patel 1978, Tindel and Nisonson 1992, Christoforakis et al. 2006). While some studies note a lack of

correlation between the size of the medial plica and the severity of the chondral lesions (Christoforakis et al. 2006, Lyu and Hsu 2006), a recent study described milder chondral lesions in patients with smaller medial plicae, as opposed to more severe chondral lesions in patients with larger plicae (Kan et al. 2015). Some authors suggest normal looking plicae could be symptomatic without impinging on articular surfaces (Irha and Vrdoljak 2003), and report an increase of nerve endings in plicae after trauma or overuse indicating increased pain sensitivity and sensation of pain (Farkas et al. 2004). These findings may border more towards theories of non-structural reasons for anterior knee pain (AKP) based on overload of normal structures (Dye 2005). Hence the existence of a synovial fold is undebated, but there is still controversy as to both how and whether it causes symptoms (Schindler 2014).

Symptomatic plicae are rare, and care should be taken to rule out other possible causes for symptoms, like ligamentous instability, patellofemoral maltracking, patellar chondral lesions or meniscal tears. Clinical findings are often not very specific, which makes diagnosing a symptomatic plica difficult. The usefulness of magnetic resonance imaging as a preoperative diagnostic tool has been studied (Jee et al. 1998, Garcia-Valtuille et al. 2002, Boles et al. 2004, Kang et al. 2016), and sensitivity up to 95% and specificity up to 81% have been reported (Vassiou et al. 2015). On the other hand a study of 23 symptomatic knees with a large plica reported that magnetic resonance imaging was non-diagnostic in 87% of the cases (Uysal et al. 2008). Hence performance of magnetic resonance imaging in detecting plicae, and distinguishing symptomatic and normal plicae, remains subject to some controversy (Garcia-Valtuille et al. 2002, Uysal et al. 2008, Vassiou et al. 2015). The diagnosis is usually clinical and remains a diagnosis of exclusion (Kent and Khanduja 2010).

Treatment of a symptomatic plica is primarily conservative (Griffith and LaPrade 2008, Al-Hadithy et al. 2011), but if symptoms persist arthroscopic resection may be considered. Division of the plica has been associated with formation of scar tissue and returning of symptoms (Patel 1978, Hardaker et al. 1980, Dorchak et al. 1991, Johnson et al. 1993), and complete resection has therefore been recommended. It should nevertheless be kept in mind that excessive resection might damage stabilizing soft tissues and predispose to subluxation tendencies (Schindler 2014, Erickson et al. 2016) and some hence advocate a subtotal excision (Guney et al. 2010). Medial plicae are often associated with other pathology in the knee joint, or vice versa, and it has been recommended the other pathology be assessed and treated first hand (Griffith and LaPrade 2008).

Studies with limited follow-up have demonstrated that symptomatic plicae can be successfully treated with arthroscopic resection (Vaughan-Lane and Dandy 1982, Nottage et al. 1983, Hansen and Boe 1989, Dorchak et al. 1991, Maffulli et al. 1993, Flanagan et al. 1994, Guney et al. 2010, Kan et al. 2015) and most patients are able to return to sporting activities within 3-6 weeks (Schindler 2014). Factors that have been suggested to be associated with favourable outcome are young patient age, localised symptoms of short duration and absence of other intra-articular pathology (Schindler 2014).

2.4 Articular cartilage lesions of the patellae

Articular cartilage lesions of the patellae, often referred to as chondromalacia patellae, are common and lack the ability to heal spontaneously (Harris et al. 2012). They can be found as incidental findings in up to 30% of patients having arthroscopic treatment for other pathologies (Elson et al. 2013), and are generally more common in adolescents and young adults (Samim et al. 2014). Articular cartilage lesions of the patellae are a common finding in military conscripts with knee complaints, but are generally considered to be found predominantly in females (Macmull et al. 2012). Not all cartilage lesions of the patella cause pain and the correlation between patellar cartilage lesions and anterior knee pain is controversial.

Structural abnormalities, knee trauma, weakness of the quadriceps muscle and vascular insufficiency within the subchondral bone are considered to be possible contributing factors to the appearance of articular cartilage lesions of the patella (Macmull et al. 2012, Werner 2014, Duran et al. 2016). Several reports evaluate different variations in morphology as probable causes. One recent study noted that Outerbridge grade 3-4 articular cartilage lesions of the superior and inferior parts of the patella were associated with a lower sagittal patellar tilt (Aksahin et al. 2016). Another study notes a correlation between a high sulcus angle, low trochlear depth and patellar lateral tilt, and the presence, but not severity, of chondral lesions of the patella (Tuna et al. 2014). These aberrations entail a less optimal positioning of the patella in relation to the trochlea it glides on, thus creating pressure on the chondral surface greater than it can withstand. Hence several surgical techinques aiming at enhancing morphology have been used as treatment for nontraumatic chondral lesions of the patella, but none seem to have been entirely successful (Macmull 2016). The pain does not seem to originate from the damaged chondral

tissue, which is not innervated, but rather from irritated synovial lining or bone (Dye 2005, Houghton 2007, Elson et al. 2013).

Early detection of patellar chondral lesions, with noninvasive methods, has been considered benificial in delaying or preventing possible progression to osteoarthritis (Harris et al. 2012, Samim et al. 2014) Other studies suggest that patellar chondral lesions may not be precursors of osteoarthritis (Macmull et al. 2016). For diagnosing articular cartilage lesions of the patellae arthroscopy remains the gold standard, but arthroscopy is invasive and binds limited health resources (Pihlajamäki et al. 2010). Magnetic resonance imaging is widely used for detecting internal derangements of the knee and reportedly more accurate than physical and radiographic examinations for detecting chondral injuries (Danieli et al. 2016). Review articles reveal significant heterogeneity in both magnetic resonance imaging systems and sequences used in evaluation of chondral lesions, making comparison of reports difficult (Harris et al. 2012). Conventional magnetic resonance imaging sequences, including T1 and T2 spin echo (SE), fast spin echo (FSE) and gradient echo (GRE), seem to underdiagnose (12-15%) more than overdiagnose (3.8-4.2%) patellar defects (Harris et al. 2012). Great effort is being put into finding protocols and sets of sequences more accurate for diagnosing chondral patellar lesions, and we might see some stabilization and standardization over time.

The ability of magnetic resonance imaging to detect arthroscopically confirmed patellar chondral lesions, in other words the sensitivity of magnetic resonance imaging, is reportedly low (13%) for milder lesions, but improves markedly (83%) with the severity of lesions (Pihlajamäki et al. 2010), with an overall sensitivity of around 70% (Kokkonen et al. 2013, Samim et al. 2014). Specificity, i.e. the ability of magnetic resonance imaging to not identify a chondral defect when one is confirmed not to be present during arthroscopic knee surgery, is reportedly around 85% (Pihlajamäki et al. 2010, Harris et al. 2012, Samim et al. 2014). Improved magnetic resonance imaging magnet strength is expected to further improve resolution and fat suppression, and hence improve visualization of chondral structures (Kuikka et al. 2006). The accuracy, or ability of magnetic resonance imaging to correctly identify and characterize chondral defect depth and area, was nevertheless at similar levels (84%) in a recent review of 13 studies using a magnet strength of minimum 1.5 Tesla (T) (Harris et al. 2012). New techniques, like delayed gadolinium-enhanced magnetic resonance imaging of the cartilage (dGEMRIC) and delayed cone beam computed tomography (CBCT) are expected to enable the identifying of more subtle chondral lesions (Macmull et al. 2012, Kokkonen et al. 2013).

3 AIMS OF THE STUDY

The aims of this study were as follows:

I   to assess the outcome of arthroscopic fixation of osteochondritis dissecans of the knee with bioabsorbable pins and nails in young adults.

II   to assess the long-term outcome after surgical excision of a symptomatic bipartite patella, as well as the incidence of, and possible anatomic deviations associated with, painful bipartite patella in male conscripts.

III   to assess the long-term outcome of arthroscopic resection of medial plica and the association between symptoms and outcome in the follow-up.

IV   to assess the sensitivity of 1.0T magnetic resonance imaging for detecting articular cartilage lesions of the patellae and the association between clinical findings and grading of articular cartilage lesions of the patellae.

4 MATERIALS AND METHODS

The study was performed at the Department of Orthopaedic Surgery, Central Military Hospital, Helsinki, Finland and the Centre for Military Medicine, Research Department, Helsinki and Lahti, Finland. The studies were approved by the medical ethics committee of the Central Military Hospital and the Institutional Review Board of the Finnish Defence Forces' Department of Medical Services. For follow-up data collection an informed consent was obtained from each person attending a follow-up examination.

Study populations were military conscripts performing their compulsory military service. All Finnish men become liable for compulsory periodic military service at the age of 18 years, the majority of the military conscripts being 19 years old at the beginning of their basic training. Female citizens have had the opportunity to volunteer for military service since 1995. During the study period over 80% of all Finnish males aged 18 to 29 years completed a service period ranging from 6 to 12 months. The patients selected for our studies comprised young military trainees who had passed their entry medical examination as healthy and were able to perform physically demanding military training. The military training, with physical and combat training, includes physical exercise that causes increased loads to the lower limb, and especially to knees because kneeling and crawling are often included in the training activities. Due to the compulsory nature of the military service, the military conscripts present an extensive sample of the general population of young adult males is Finland.

We examined outcomes of surgical interventions (studies I-III), incidence (study II), correlation of symptoms with anatomic deviations (study II) or with outcome (study III), and we examined the diagnostic abilities of magnetic resonance imaging (studies III and IV). All operations and clinical follow-up examinations were performed at the Central Military Hospital in Helsinki, which provided all surgical services for the entire armed forces of Finland at that time.

4.1 Study populations (I-III)

4.1.1 Study population I

Over a period of 9 years, from May 1990 to November 1999, 42 military conscripts with osteochondritis dissecans of the knee were treated at the Central Military Hospital with arthroscopic fixation using bioabsorbable self-reinforced poly-L-lactide (SR-PLLA) pins and nails (Figure 6). The procedures were performed by 6 orthopaedic surgeons of the institution, and the method of fixation was determined according to the judgement and personal preference of the surgeon in charge. Both pins and nails were approved for hospital use and routinely available, and no hospital guidelines existed that would have advocated the use of a specific implant based on the patient or lesion characteristics. The patients were retrospectively identified and invited for follow-up examinations. 27 patients, altogether 30 knees, were available for follow-up and the method of fixation was pins in 17 knees and nails in 11 knees.
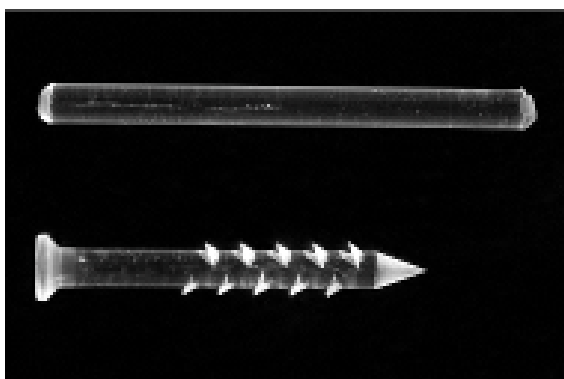

Figure 6. Bioabsorbable fixation devices used in study I; the poly-L-lactide pin (above) and the poly-L-lactide nail (below).

4.1.2 Study population II

Over a period of 11 years, from January 1985 to December 1995, 32 military conscripts with a painful bipartite or multipartite patella underwent excision of a superolateral or lateral patellar fragment at the Central Military Hospital. After an

initial arthroscopy an excision of the accessory fragment was performed through a separate longitudinal incision, with the exception of one patient who had an arthroscopical excision. Six orthopaedic surgeons performed the procedures, all using the same approach and technique. The patients were retrospectively identified and invited for follow-up examinations. Five of the 32 patients were lost to follow-up; four were deceased, and one could not be located. Of the 27 patients operated on who were available for follow-up, two patients were excluded because of extensive subsequent knee surgery unrelated to the bipartite patella. Altogether 25 patients, with 25 surgically treated symptomatic bipartite fragments, participated in the final follow-up.

The 349,054 conscripts who performed their compulsory military service between 1985 and 1995 formed the population at risk, and we used this total number of conscripts to calculate the incidence of patients with painful bipartite patella undergoing surgical treatment during this 11-year period.

4.1.3   Study population III

Over a period of 6 years, from 1997 to 2002, 36 military conscripts with knee pain treated at the Central Military Hospital met the following criteria; a magnetic resonance imaging examination followed by arthroscopy of the same knee and 1) a sole postoperative diagnosis of medial plica, 2) normal preoperative magnetic resonance imaging of the knee, and 3) an arthroscopic plica resection performed after magnetic resonance imaging. The patients were identified and it was noted that three patients were lost to follow-up; two were deceased and one had moved abroad. 33 patients were invited for follow-up examinations; 25 patients, in total 34 knees, were available for follow-up.

4.2   Outcome measurements of study I-III

The original complete medical records including plain radiographs (studies I and II) and magnetic resonance images (study III), were reviewed and details of the surgical procedure were listed. The patients invited for follow-up answered a questionnaire recording information about their functional outcome after surgery and underwent a physical examination (studies I-III) and radiologic evaluations, including plain radiographs (studies I and II) and magnetic resonance imaging

(study I). Patients were asked about their symptoms, general health status, and participation in athletic activities before and after surgery. Possible previous or subsequent operations were recorded from the chart reviews and patient interviews at the time of follow-up.

The functional outcome at follow-up was measured by the Kujala (studies I-III) and Lysholm (study III) scores (Kujala et al. 1993, Lysholm and Gillquist 1982); a score of 95 points or more was considered excellent, 94-85 points good, 84-65 points fair, and less than 64 points was considered a poor result. A ten-point (0 to 10 cm) visual analogue scale (VAS) was used to determine the degree of subjective pain experienced by the patients at follow-up; a score of zero denoting none, one to three light, four to six moderate, seven to nine hard, and ten the worst imaginable pain. The body mass index (BMI), body weight in kilograms divided by body height in meters squared (kg/m2), was registered. For an adult male younger than 30 years, a BMI of 18.5 to 24.9 was considered normal (Llewellyn-Jones and Abraham 1984, WHO 1995).

4.3   Classification systems and radiology (studies I-III)

4.3.1   Study I

The location of the osteochondritis dissecans lesion was categorized according to two classification systems, one by Aichroth (Figure 7) to assess the location and extent of the lesion on anteroposterior radiographs (Aichroth 1971), and the other by Harding to estimate the location on lateral radiographs (Harding 1977).
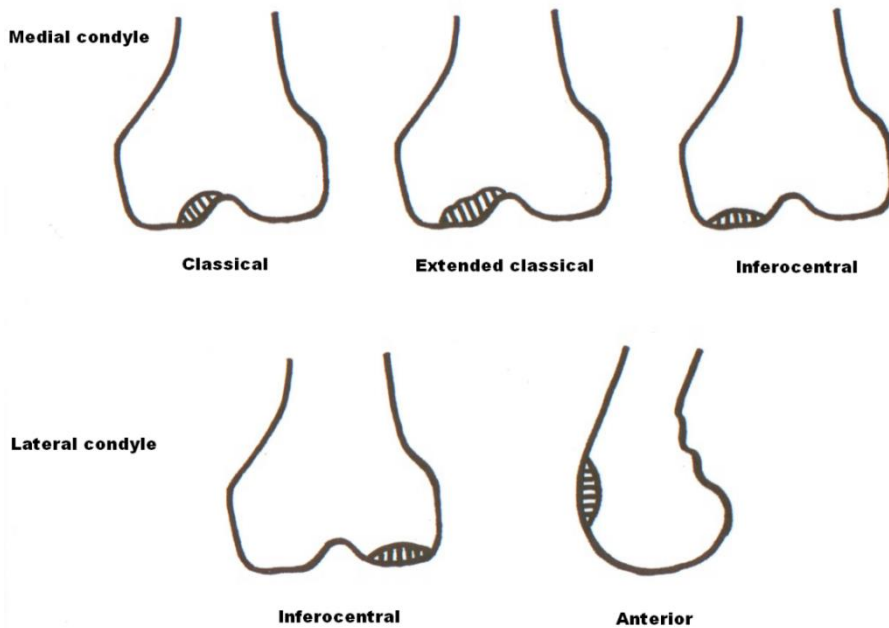
Figure 7. Locations of osteochondritis dissecans lesions as classified by Aichroth (Aichroth 1971). Modified from original publication I (Weckström et al. 2006) with permission of SAGE Publications.

The lesion size was determined by the product of the mediolateral width on the coronal and the anteroposterior width on the sagittal magnetic resonance images. Based on the arthroscopic examination, the lesions were classified into groups as described by Guhl (Guhl 1982); intact lesions, lesions showing signs of early separation, partially detached lesions, or craters with loose bodies. The plain radiographs, preoperatively, postoperatively, and at final follow-up, consisted of anteroposterior, lateral, and tunnel views. At the final follow-up, a magnetic resonance imaging 1.0T scanner (Signa Horizon, GE Medical Systems, Milwaukee, USA), and a knee coil with a field of view of 10-16 cm were used. Slice thickness was (3)-4 mm, with a 0.5 or 1.0 mm intersection gap. Sagittal, proton density, spin-echo sequence images with fat suppression, or sagittal, T1-weighted, spin-echo sequence images were obtained. T2-weighted fast spin-echo sequences with fat suppression were obtained in the axial and coronal images. Evaluations of the radiographs and magnetic resonance images were performed by three of the authors, including a musculoskeletal radiologist, in consensus and blinded to clinical data.

4.3.2 Study II

The location of the accessory bipartite fragment was categorized from radiographs according to a classification introduced by Erich Saupe, Type I involving the inferior pole, Type II the lateral margin, and Type III the superolateral quadrant of the patella (Saupe 1921).

In order to evaluate possible anatomic deviation associated with a painful bipartite patella we recorded the following measurements from radiographs. Using the tunnel view radiographs, the patellar angle (Figure 8A) was measured from a line connecting the anterior aspect of the femoral condyles and a second line along the lateral facet of the patella (Laurin et al. 1978). Likewise, the sulcus angle (Figure 8B) was measured from the lines extending from the deepest point of the intercondylar sulcus, medially and laterally, to the tops of the femoral condyles. The sulcus angle was then bisected and this reference line was compared with a line drawn from the apex of the sulcus angle through the lowest point of the articular ridge of the patella (congruence angle) to detect possible lateralization of the patella (Merchant et al. 1974). On lateral radiographs, the ratio of the patellar tendon length was measured against the greatest length of the patella (Insall-Salvati ratio, Figure 8C) to determine the existence of patella alta or patella profunda (Insall and Salvati 1971). The Kellgren-Lawrence scale (Kellgren and Lawrence 1957) was used to grade osteoarthritic changes on the final follow-up radiographs.
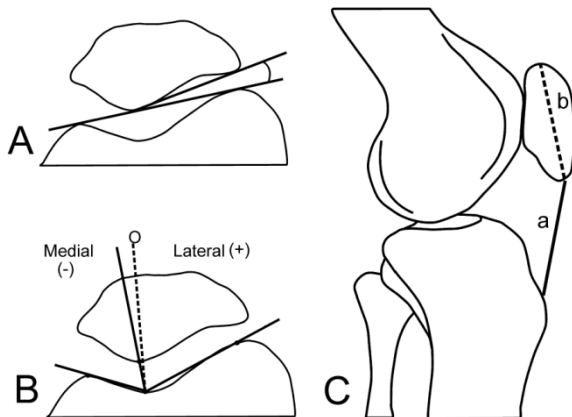

Figure 8. Measures of (A) the patellar angle, (B) the sulcus angle, and (C) patella alta or patella profunda (Insall-Salvati ratio). Reprinted from original publication II (Weckström et al. 2008), with permission of Springer.

4.3.3   Study III

The size of the medial plicae seen in arthroscopy were classified as small, moderate, shelf-like or fenestrated; corresponding to the common classification often referred to as the Sakakibara classification scheme with type A indicating a cordlike elevation in the medial wall; type B, a shelf-like formation not covering the anterior surface of the medial condyle; type C, a large shelf-like formation covering the anterior surface of the medial condyle; and type D, a fenestrated plica (Sakakibara 1976).

Images were preoperatively obtained on a 1.0T scanner (Signa Horizon, GE Medical Systems, Milwaukee, USA), using a knee coil with a field of view of 10-16 cm. Slice thickness was 3 to 4 mm, with a 0.5 or 1.0 mm intersection gap. Sagittal T1 and T2* images, coronal proton density images with fat suppression, and either axial gradient-echo (3D T1 FSPGR) images, axial proton density images or axial T2-weighted images with fat suppression were obtained. Intra-articular contrast medium was not used. For the follow-up two musculosceletally-oriented radiologists reevaluated the magnetic resonance images in consensus, blinded to clinical data and previous radiological investigations, and with the emphasis on identifying medial plicae. The plicae were graded from axial images according to the above-mentioned Sakakibara classification scheme (Figure 9) (Sakakibara 1976).
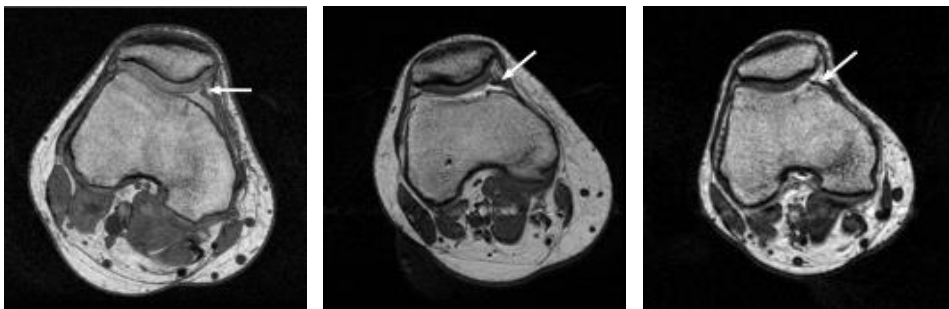

Figure 9.   Medial plicae classified on magnetic resonance images as Sakakibara type A, B and C respectively (Sakakibara 1976). Reprinted from original publication III (Weckström et al. 2010), with permission of Elsevier.

4.4   Study population, outcome measures and radiology of study IV

The study population of study IV consisted of 74 male conscripts with articular cartilage lesions of the patella, diagnosed with arthroscopy between 1999 and 2003 at the Central Military Hospital, who met the following inclusion criteria. A sole diagnosis of articular cartilage lesions of the patella diagnosed by arthroscopy, and previous magnetic resonance imaging of the knee, no more than 3 months before arthroscopy. Exclusion criteria were previous fracture of the distal tibia or patella. In cases of bilateral articular cartilage lesions of the patellae (15 knees) only one knee per person was randomly chosen.

Patient medical histories were studied and collected information was recorded in a database. Duration of knee symptoms was classified into one of three categories: 1) less than 1 year, 2) 1 to 2 years, and 3) over 2 years. Clinical features were also classified into one of three categories: 1) discomfort and pain in anterior patella without further symptoms or findings, 2) typical symptoms of anterior knee pain (AKP), namely pain after walking stairs and prolonged sitting, without findings in physical examination, and 3) typical symptoms of anterior knee pain with crepitus and pain during active movement of the patella.

All patients with anterior knee pain symptoms were initially treated conservatively with anti-inflammatory medication and physiotherapy, and temporarily exempted from all strenuous physical activity and military training. Patients not responding to conservative treatment were referred to orthopaedic consultation at the Central Military Hospital. In general, arthroscopy was chosen when the response to nonsurgical treatment was insufficient and a reliable method was needed to verify suspected articular cartilage lesions of the patellae, or to differentiate between articular cartilage lesions of the patellae and other internal derangements of the knee, such as medial plica.

Plain radiographs, including anteroposterior, lateral and Merchant views, were routinely obtained in all of the patients before physical examination by an orthopaedic surgeon. Magnetic resonance imaging was performed with a 1.0T scanner (Signa Horizon, GE Medical Systems, Milwaukee, USA), using a standard knee coil with a field of view of 10-16 cm. The knee was extended and quadriceps was relaxed during the scanning. Slice thickness was 3 to 4 mm, with a 0.5 or 1.0 mm intersection gap. Sagittal proton density (PD) spin echo sequence images with fat suppression or sagittal T1-weighted spin echo sequence images were obtained. Axial T1- and T2-weighted sequences with fat suppression were obtained, as well as coronal T2-weighted coronal images.

The images were initially evaluated by a musculoskeletal radiologist on duty using a standard magnetic resonance imaging interpretation protocol. For the purpose of this study, another musculoskeletal radiologist reevaluated the images blinded to previous magnetic resonance imaging results and arthroscopy findings. In cases in which the reevaluation differed from the original (3 cases), a decision was reached by consensus. Grading was made based on the arthroscopic grading system of Shahriaree: 0, normal; 1, softening or blister by high signal intensity and swelling of the cartilage on magnetic resonance images; 2, fissuring; 3, fragmentation and fissuring; 4, full thickness fissure and exposed bone (Shahriaree 1985).

4.5   Statistical methods

4.5.1   Statistical methods for the outcome variables for studies I-III

4.5.1.1   Study I

The similarity of the two osteochondritis dissecans groups (pins and nails) at the beginning of the study period, and the differences in the outcomes between the two groups, were tested using Pearson's chi-square test. Student's t-test was used to test differences in the continuous normally distributed data, and the Mann-Whitney U-test and the Kruskall-Wallis test in the continuous skewed data between the classes. Correlation analysis was used to explore the associations between the continuous variables. Mean values were presented in the continuous unskewed data, and median values in the continuous skewed data, with range (min-max). A p-value of $\leq$ 0.05 was considered to be significant. We used SPSS 12.0.1 for Windows software (version 12.0; SPSS Inc, Chicago, Ill) for statistical analysis.

4.5.1.2   Study II

Mean values were presented in the continuous unskewed data, and median values in the continuous skewed data with range (min-max). We used SPSS statistical software (version 14.0; SPSS Inc, Chicago, IL) to compute descriptive statistics.

Mean values were calculated for the continuous unskewed data, and median values for the continuous skewed data, with range (min-max). Associations between groups in continuous skewed variables were measured using the Kruskall-Wallis test. Bivariate correlations were calculated for continuous variables. Cross tabulations and chi-square test were used when testing associations between classified variables. We used SPSS for Windows software (version 14.0; SPSS Inc, Chicago, IL) for statistical analysis. The significance level was defined at $p<0.05$ for all tests.

4.5.2 Statistical methods for calculating sensitivity in data IV

To determine the diagnostic sensitivity of the 1.0T magnetic resonance imaging and symptoms and physical examination, the magnetic resonance imaging findings, symptoms, and clinical findings were compared with the arthroscopic findings, the arthroscopic result serving as gold standard. A single table analysis was used to calculate the sensitivity of magnetic resonance imaging and clinical symptoms. A chi-square test was used in two-way tables and the level of significance was set to $p=0.05$. Ninety-five percent confidence intervals were calculated by Wilson's method. When calculating results for grade I articular cartilage lesions of the patellae, only arthroscopically detected grade I lesions were considered positive (gold standard) for cartilage lesions and compared to magnetic resonance imaging results in which grade 0 was considered negative and grades I to IV positive. Results for grades II-IV were calculated respectively, arthroscopically detected grade II-IV lesions were considered positive and compared to magnetic resonance imaging results in which grade 0 was considered negative and grades I-IV positive. SPSS 17.0 for Windows was used for statistical analysis.

5 RESULTS

Hypothesis	Study population	Results
Study I Bioabsorbable pins and nails are equally well suited for arthroscopic fixation of osteochondritis dissecans of the adult knee.	27 males (30 knees)	Excellent-good functional outcome for fixation with bioabsorbable pins 35%, and nails 73% (p=0.028).
Study II Surgical excision of a painful bipartite patella in young adults has good long term outcome. Bipartite patella is associated with anatomic deviances.	25 males (25 knees)	Excellent-good functional outcome for 96% of patients. Anatomic deviances, other than bipartite patella, were rare.
Study III Arthroscopic resection of a plica in a symptomatic knee relieves symptoms. Clinical examination and MRI can be used to detect plica and determine need for arthroscopy.	24 males 1 female (34 knees)	Excellent-good functional outcome for 68% of patients. Clinical examination and routine MRI detect medial plicae poorly.
Study IV MRI and symptoms and clinical findings can be used to identify and grade articular cartilage lesions of the patella.	74 males (74 knees)	MRI had 100% (95% CI: 85-100%) sensitivity for grade II-III lesions, overall sensitivity was 66% (95% CI: 53-74%). Symptoms and clinical findings showed poor sensitivity (≤39%) and did not correlate with grade of lesion (p=0.61).

5.1 Osteochondritis dissecans

5.1.1 Main characteristics

All patients of the study were young adult males with closed physes. The average length of the follow-up was 5.7 years (range, 3-12) in the pin group and 5.0 years (range, 3-12) in the nail group (p=0.11). The mean age at surgery was 20 years (range, 19-22) in the pin group and 21 years (range, 19-26) in the nail group (p=0.055). The mean body mass index at the time of surgery was 23 in both groups with a range of 18-32 in the pin group and 20-27 in the nail group (p=0.756). Most patients reported frequent leisure-time athletic activities before surgery. One patient in the pin group had bilateral patellar chondromalacia, which had been arthroscopically detected earlier. Arthroscopic drilling of the osteochondritis dissecans fragment had previously been performed in one patient of each group, and in the pin group fixation with glue in one patient and removal of loose bodies in another had been performed.

Characteristics	Pin group	Nail group	P-value
	Mean (range)	Mean (range)	
Age at surgery	20 years (19-22)	21 years (19-26)	0.055
Weight	78 kg (63-105)	79 kg (62-97)	0.927
Height	183 cm (170-196)	183 cm (174-190)	0.821
Body mass index	23 kg/m² (18-32)	23 kg/m² (20-27)	0.756

Table 3. Preoperative characteristics of the pin and nail group. Reprinted from original publication I (Weckström et al. 2006), with permission of SAGE Publications.

Prior to arthroscopic surgical treatment, all military conscripts reported pain related to combat exercise and marching. In addition, one-third of the patients in both groups had experienced pain related to running, whereas symptoms associated with walking, kneeling/crawling, or climbing stairs were rare. The average time from first symptoms to surgery was 25 months (range, 2-132) in the pin group and 30 months (range, 1-72) in the nail group (p=0.54). There was no

statistically significant difference between the two groups in terms of length of follow-up, age, BMI or duration of symptoms.

5.1.2 Lesion characteristics

The average lesion size was 461 mm² (range, 200-900 mm²) in the pin group and 426 mm² (range, 225-675 mm²) in the nail group (p=0.87). The lesion was located in the medial condyle in 86% and the lateral condyle in 13% of the knees. According to the Aichroth classification the medial lesion location was classical in 4 knees in the pin group and 2 knees in the nail group, extended classical in 11 knees in the pin group and 7 knees in the nail group, and inferocentral in 2 knees in the pin group. The lateral lesions were correspondingly inferocentral in 2 knees in the pin group and in 1 knee in the nail group, and anterior in 1 knee in the nail group (Figure 10).
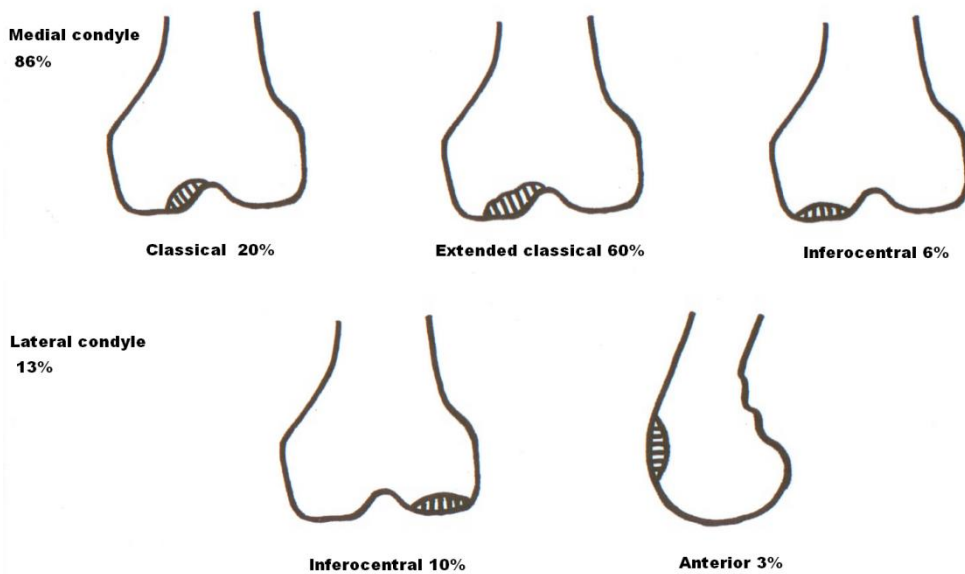

Figure 10. Distribution of the osteochondritis dissecans lesion location in study I. Aichroth classification (Aichroth 1971). Modified from original publication I (Weckström et al. 2006) with permission of SAGE Publications.

Lateral radiographs, according to the Harding classification, showed 16 lesions located in the 'area at risk', i.e. in the area between a line extended anteriorly from the density of the roof of the intercondylar notch and a line extended distally from the posterior cortex of the distal femoral diaphysis (Harding 1977), and 3 located posteriorly in the pin group, and in the nail group, 5 lesions located in the 'area at risk', 5 lesions posteriorly, and one lesion located anteriorly (p=0.06).

The appearance of the lesion was, according to the Guhl classification (Guhl 1982), intact (grade I) in 2 knees in the pin group and 1 knee in the nail group, showed signs of early separation (grade II) in 9 knees in the pin group and 5 knees in the nail group, was partially detached (grade III) in 7 knees in the pin group and 5 knees in the nail group, and was a crater with loose body (grade IV) in 1 knee in the pin group (p=0.87). There were 10 lesions of the right and 9 lesions of the left knee in the pin group, and 3 lesions of the right and 8 lesions of the left knee in the nail group. There was no statistically significant difference between the two groups in terms of lesion size, location or arthroscopic appearance.

5.1.3 Surgery details

Fixation of the lesion was performed arthroscopically in all patients; an additional arthrotomy was required in 2 cases in each group. Of the three patients with osteochondritis dissecans lesions in both knees, two underwent surgery for both lesions. The majority of the fragments in both groups were fixed in situ (Figure 11), i.e. 18 (95%) fragments in the pin group and 9 (81%) fragments in the nail group.

Figure 11. Intraoperative arthroscopic photograph of a medial osteochondritis dissecans lesion, after in situ fixation with three bioabsorbable pins. Reprinted from original publication I (Weckström et al. 2006) with permission of SAGE Publications.

The lesion bed was debrided in one case in the pin group where the fragment was completely detached and in two cases in the nail group where the fragment was partially detached and could be hinged open. Additional drilling through the fragment to enhance healing was performed in 6 knees (32%) in the pin group and 2 knees (18%) in the nail group. In the one case of a loose fragment in the pin group, fibrin glue was used in addition to pin fixation (Figure 12). No bone grafting was performed in any of the cases in this study. The technique (other than choice of implant) used for the fixation was chosen according to the degree of separation of the fragment.

Figure 12. Left. Empty crater in the medial condyle on preoperative anteroposterior non-weightbearing radiograph. Right. Good consolidation of salvaged and reattached fragment on postoperative anteroposterior non weight-bearing radiograph at final follow-up, 12 years after fixation with bioabsorbable pins. Reprinted from original publication I (Weckström et al. 2006) with permission of SAGE Publications.

Self-reinforced poly-L-lactide (SR-PLLA) pins or nails were used for fixation of the fragment. The pins measured 1.5 mm and 2.0 mm in diameter, and 20-25 mm in length. The nails measured 1.5 mm in diameter and 16 mm in length. Pins were used in 19 and nails in 11 knees. The severity (p=0.86) or size (p=0.87) of the lesion was not associated with the choice of implant (pin or nail). The average number of implants used for fixation of the fragment was 3.5 (range 2-5) in the pin group and 3.6 (range 2-7) in the nail group (p=0.68).

In addition to osteochondritis dissecans fragment fixation, partial meniscus resection was performed in one knee in each group, and in the pin group, resection

of the medial synovial plica in one knee, anterior cruciate ligament reconstruction in one knee, minor chondral revision in 4 knees, and removal of a loose body in one knee were performed. Three patients in the pin group had a simultaneous procedure performed to the other knee due to reasons other than osteochondritis dissecans; i.e. lateral release, synovial resection, and operative treatment of Osgood-Schlatter disease.

5.1.4 Immediate post-operative follow-up and treatment

One patient in the pin group developed bacterial arthritis in the operated knee, requiring arthroscopic lavage on the third postoperative day. He was given oral antibiotics for about 7 weeks, and recovered successfully. During the postoperative follow-up a patient in the pin group developed a transient serosanguinous knee effusion, which subsided after aspirations at 3, 6 and 8 weeks postoperatively.

The median duration of the hospital stay before the patient returned to the garrison was 4 days in both groups, with a range of 2 to 34 days in the pin group and 3 to 7 days in the nail group (p=0.95), the aforementioned complication of bacterial arthritis accounting for the longest stay. After discharge, most patients visited the outpatient clinic for follow-up, two visits being the average in both groups (range, 0-6 in the pin group and 0-5 in the nail group) (p=0.68).

Postoperative treatment was the same for both groups; from the first postoperative day quadriceps muscle exercises were encouraged, as well as early mobilization with partial weight-bearing using crutches (on average 35 days, with a range of 1-60 days in the pin group, and 28 days, with a range of 15-45 days in the nail group) (p=0.28). Since the patients were all operated during their compulsory military service, they were closely followed up by an orthopedic surgeon at the outpatient clinic to ensure that the patients were symptom-free, had painless weight-bearing, and full range of motion of the knee before returning to military training. Both groups returned to military service, and training, after an average of 12 weeks (range, 4-31 weeks in the pin group, and 3-23 weeks in the nail group).

A subsequent reoperation in seven patients was necessary in the pin group; drilling through the fragment was performed in two knees less than a year after primary fixation to enhance healing, minor chondral revision was performed in three knees, removal of a loose body was performed in one knee, and refixation with bioabsorbable pins in one knee after about 4 years. In the nail group, there were three reoperated patients; one later minor chondral revision, one removal of a

loose body, and in one patient, mosaicplasty of the osteochondritis dissecans lesion was performed 3 years after primary fixation. No loosening or protruding of fixation devices was observed during the reoperations.

5.1.5 Functional outcome

In the pin group, using the Kujala outcome score, 35% (6 patients) had excellent to good results, 8 patients had fair, and 3 had poor results. In the nail group, 73% (8 patients) had excellent to good results, 3 patients had fair results, and none had poor results (Figure 13). The median Kujala score for the pin group was 81 (range, 63-100), compared to 91 (range, 72-98) for the nail group, the difference being statistically significant (p=0.028). The median visual analogue scale score for the pin group was 3.5 (range, .5 to 7.5) and for the nail group 1.5 (range, .5 to 5). The difference between the groups was, however, not significant (p=0.13).
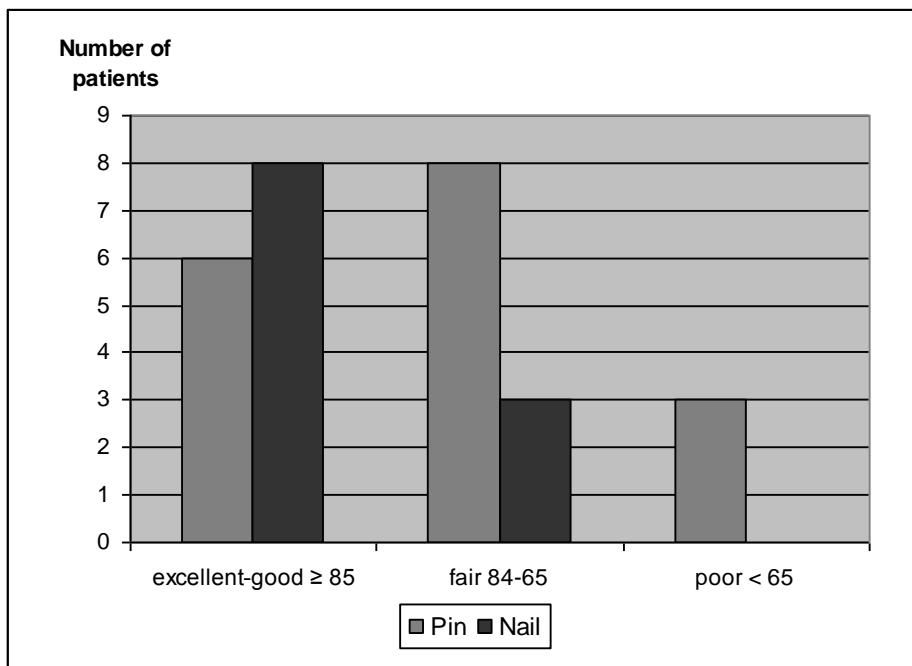

Figure 13. A comparison of the functional outcome of the pin and nail fixation as measured by the Kujala score (Kujala et al. 1993). The median Kujala score for the pin group was 81 (range, 63-100), compared to 91 (range, 72-98) for the nail group (p=0.028). Reprinted from original publication I (Weckström et al. 2006) with permission of SAGE Publications.

The severity of the primary lesion as classified by Guhl's method was not associated with the outcome of the surgery as measured by the Kujala score (p=0.3) or the visual analogue scale score (p=0.2). Similarly, there was no significant correlation between the lesion size and the outcome of the surgery as determined at the follow-up by the Kujala (p=0.98) and the visual analogue scale scores (p=0.35).

During the physical examination at the final follow-up, no limping was detected in the patients. The range of knee motion was full in all but three patients (two from the pin group and one from the nail group), who had an average flexion deficit of 22 degrees (range 20-25 degrees) compared with the range of motion of the contralateral knee. There were no clinical signs of knee joint effusion at the final follow-up examination. Three knees in the nail group and 7 knees in the pin group exhibited atrophy in the quadriceps muscle, and one knee in the nail group exhibited instability at the final follow-up.

On magnetic resonance images at final follow-up, the fragment was seen properly repositioned in all the knees. Signs of incomplete bone consolidation, i.e. a fluid interface between the osteochondritis dissecans fragment and the parent bone (Figure 14; left) or sclerosis of the fragment (Figure 14; right) could be detected in 9 cases of the pin group and 3 cases of the nail group. There were seven fragments with pin fixation that appeared sclerosed, implying imminent necrosis. The difference to the nail group, with no sclerosed fragments, was statistically significant (p=0.033). There was also a positive correlation (0.6348) between the fragment size and the appearance of sclerosis in the follow-up magnetic resonance imaging evaluation.

Seven knees showed early signs of arthrosis (Figure 15; left), but the distribution between the groups was not significant. Effusion was seen in 12 knees of the pin group and 6 knees of the nail group (p=0.57). There was no osteolysis around the implants. The overall magnetic resonance imaging result was excellent (Figure 15; right) in four cases, i.e. there were no signs of incomplete bone consolidation, effusion, or arthrosis.
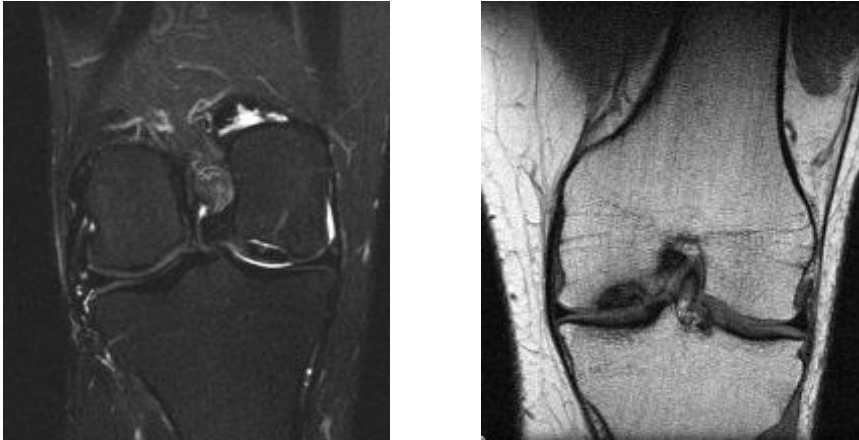
Figure 14. Left: Coronal T2-weighted magnetic resonance images show synovial fluid around the osteochondritis dissecans fragment at final follow-up, 5 years after fixation, indicating incomplete bone consolidation and an unstable fragment. Functional outcome was fair. Right: Coronal T1-weighted magnetic resonance images depict sclerosis of the medial osteochondritis dissecans fragment and incomplete bone consolidation at follow-up, 8 years after pin fixation. Functional outcome was excellent. Reprinted from original publication I (Weckström et al. 2006) with permission of SAGE Publications.
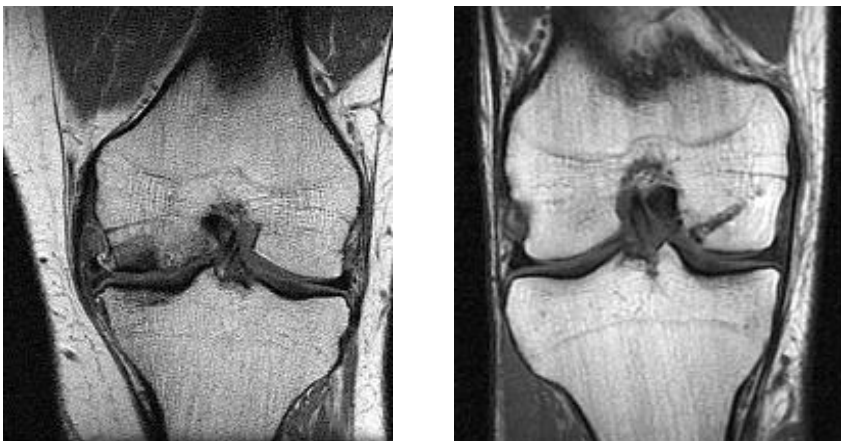

Figure 15. Left: Coronal T1-weighted magnetic resonance images show moderate arthrotic changes at final follow-up, 12 years after fixation. Right: Complete consolidation of the osteochondritis dissecans fragment as seen on T1-weighted proton density coronal magnetic resonance images at final follow-up, 6 years after nail fixation. The channel of the poly-L-lactide nail is still visible. Functional outcome was excellent. Reprinted from original publication I (Weckström et al. 2006) with permission from of SAGE Publications.

5.2 Bipartite patella

5.2.1 Main characteristics

The incidence of painful bipartite or multipartite patella, surgically treated during military service, was 9.2 per 100,000 conscripts, or 0.0092%.

All patients of the study were young adult males. The mean length of the follow-up was 15 years (range, 10-22). The median age at surgery was 20 years (range, 18-27). The mean body mass index at the time of surgery was 23.2 (range, 19.7-28.4). Twenty-four patients were active in some kind of recreational sport before surgery. Previous excision of a superolateral painful bipartite fragment had been performed 7.5 years earlier in another institution in one patient, who during military service again presented with a painful bipartite fragment at the same superolateral part of the patella. One patient had previously undergone surgery for an osteochondritis dissecans lesion, which had healed well and was not visible on magnetic resonance images taken prior to excision of the painful bipartite fragment. One patient had undergone patellar medialization 5 years prior to the excision of the painful bipartite fragment.

Characteristics	Mean (range)
Age at surgery	20 years* (18-27)
Weight	73 kg (59-89)
Height	177 cm (168-189)
Body mass index	23 kg/m² (20-28)

* median

Table 4. Preoperative characteristics of study population II.

Twenty-three patients complained of pain during exercise (marching), including two patients who also reported pain at rest or when kneeling. Two patients complained of pain associated with kneeling only. One third of the patients reported the onset of symptoms after an injury to the knee. Median duration of symptoms prior to excision was 11 months (range, 3–144 months). The initial

management for all patients with a symptomatic bipartite or multipartite patella was nonoperative, consisting mainly of restriction of activities, or rest, and nonsteroidal anti-inflammatory drugs when necessary. Operative management was chosen as method of treatment when the response to nonoperative treatment was insufficient, and prolonged incapacitating pain persisted.

5.2.2 Lesion characteristics

Nineteen of the 25 fragments (76%) were located at the superolateral part of the patella (Saupe type III; Figure 16), and six lesions (24%) were lateral (type II; Figure 17). None of the excised fragments were located at the disputed inferior pole of the patella (type I). There were 13 right and 12 left knees operated.

Figure 16. Superolateral bipartite patellar fragment (arrow) on preoperative anteroposterior radiograph. Reprinted from original publication II (Weckström et al. 2008) with permission of Springer.

Figure 17. Lateral bipartite patellar fragment (arrow) on preoperative (left) anteroposterior and (right) tunnel view radiographs. Reprinted from original publication II (Weckström et al. 2008) with permission of Springer.

5.2.3 Surgery details

Arthroscopy was first performed to rule out internal derangement, other than the bipartite patella, of the knee. The bipartite fragment was then, in 24 patients, removed by subperiosteal excision performed through a separate incision made over the unfused fragment, and the dissected part of the ligamentous structure was sutured with absorbable sutures. In one patient the removal was performed arthroscopically.

Figure 18. Site of excision (arrow) of superolateral bipartite patellar fragment at final follow-up, 14 years after excision. Functional outcome was excellent. Reprinted from original publication II (Weckström et al. 2008) with permission of Springer.

Two knees presented with three loose fragments that were all removed from the superolateral site. In ten of the 21 knees that underwent arthroscopic examination, a narrow line of indentation between the fragments, or prominence of the smaller fragment, was seen. In addition, there were slight chondromalacia-like changes on the articular surface of the fragment in ten knees. Patellar chondromalacia (grade I) was seen in two knees, neither of which required intervention. Likewise, a synovial plica was seen in two knees, but neither required resection.

Lateral retinacular release was performed in one patient who on preoperative radiographs had shown lateralization of the patella, and one patient underwent a partial meniscus resection. In one patient, excision of the bipartite fragment was performed on the right knee, while at the same time revision of medial and distal patellar chondromalacia was performed on the contralateral knee.

5.2.4 Immediate post-operative follow-up and treatment

During the immediate postoperative follow-up, two patients developed a transient nonbacterial synovitis, which subsided after two aspirations, and, in one of these patients, after an additional intra-articular injection of cortisone. One patient developed a wound infection which subsided within weeks with local treatment and per oral antibiotics.

Postoperatively, active quadriceps exercises were encouraged from the first postoperative day, as well as early mobilization with partial weightbearing using crutches for an average of 3 weeks. The postoperative mobilization was done under supervision of a physiotherapist. The patients returned to the garrison dormitory accommodation after a median hospital stay of 5 days (range, 2–8 days), and were closely followed by a physician to ensure that they were symptomless, had painless weightbearing and a normal range of motion of the knee before returning to normal military training. All patients returned to normal military training after a median of 5 weeks (range, 1–13 weeks) postoperatively.

No reoperations related to the bipartite patella occurred during the follow-up period. Three patients reported a later surgical intervention on the same knee for reasons other than the bipartite patella; one patient had arthroscopic revision of patellar chondromalacia, one patient underwent a diagnostic arthroscopy with no findings, and one patient suffered a knee injury while playing soccer and the ruptured anterior cruciate ligament was reconstructed with a hamstring tendon graft. Based on the functional Kujala scores all three patients recovered well from the previously mentioned surgical procedures.

5.2.5 Functional outcome

Excellent results (a Kujala score of ≥ 95 points) were seen in 15 patients, good results (94–85 points) in nine patients, and a fair result (84–65 points) in one patient at the final follow-up (Figure 19). The Kujala score average was 95 points (range, 75–100 points). The median visual analogue scale score of knee pain at the time of the final follow-up was 1.0 (range, 0.0–6.0).
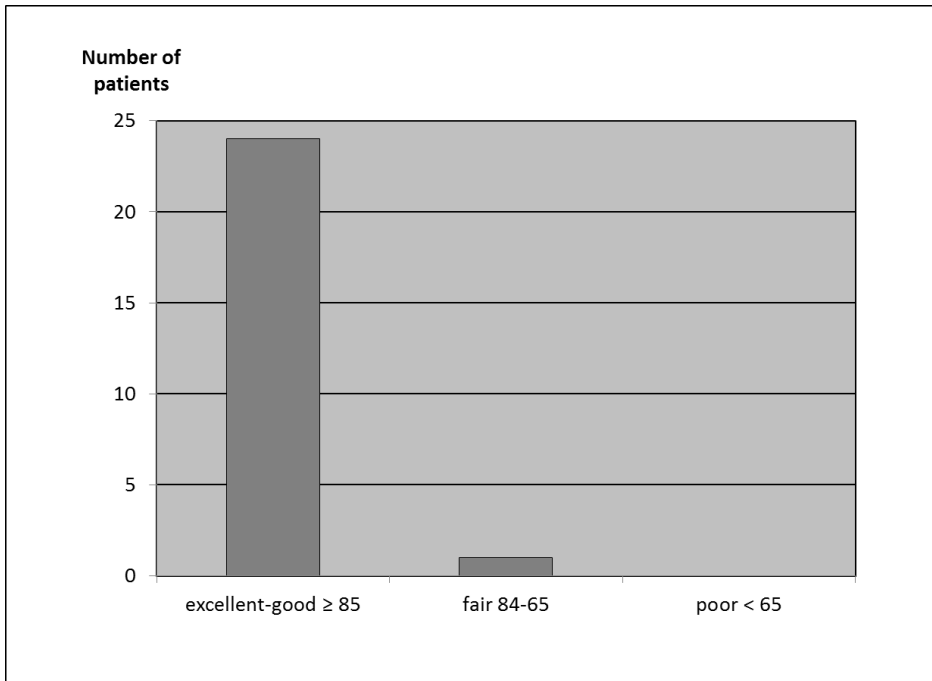
Figure 19. Functional outcome of excision of bipartite patellar fragment as measured by the Kujala score.

During the physical examination at the final follow-up, the range of motion was full and symmetric in all knees, and there were no signs of quadriceps atrophy or instability of the knee. In the patient with a fair functional outcome, flexion over 90° was painful, and there was some tenderness in the lateral parts of the patella.

On radiographs, the patellar angle opened medially in three knees, indicating the potential for patellar subluxation, while in the other 22 knees, the angle was normal (opened laterally). Two knees had a slightly shallow (150°) sulcus angle. One knee presented with slight lateralization of the patella, but the others were normal. The Insall-Salvati ratio average was 1.0 (range, 0.8–1.8). Three knees were classified as patella profunda, and the rest (22 knees) were within the normal Insall-Salvati ratio range (between 0.8–1.2).

In 23 patients, the radiographs showed no signs of complications or other adverse development. Slight formation of osteophytes (Figure 20) was seen in two knees, primarily patellofemorally. The findings were bilateral, grade 1 on the Kellgren-Lawrence scale of osteoarthritic changes (Kellgren and Lawrence 1957).

Figure 20. Slight bilateral arthrotic changes, at final follow-up 17 years after excision of a painful superolateral bipartite fragment of the left knee, as seen on (above) anteroposterior and (below) tunnel view radiographs. Reprinted from original publication II (Weckström et al. 2008), with permission of Springer.

5.3   Medial synovial plica

5.3.1   Main characteristics

All patients were young adults (24 men, 1 woman) with a total of 34 knees studied. The median follow-up time was 6.6 years (3.6 to 8.7). The median age at the time of surgery was 20 years (18–28). The average body mass index was 23.7 kg/m² (20.5–29.3). Nineteen patients reported being active and five patients being moderately active in recreational sports before surgery.

Characteristics	Mean (range)
Age at surgery	20 years* (18-28)
Weight	76 kg (58-108)
Height	179 cm (166-195)
Body mass index	23 kg/m² (20-29)

* median

Table 5. Preoperative characteristics of study population III.

Preoperatively, the patients listed various activities as pain-provoking: all 25 patients experienced knee pain during exertion such as marching or running, 19 had knee pain when kneeling and/or climbing stairs, six experienced knee pain at rest and eight in normal walking. Eleven knees had no preoperative physical findings indicative of a symptomatic medial plica, 13 knees had less specific symptoms such as crepitation, snapping or a positive McMurray test, and 10 knees presented with medial patellar pain, the most constant sign of the syndrome, with or without other less specific findings. We found no statistically significant association between symptoms (positive lateral McMurray p=0.87, positive medial McMurray p=0.45), patellar crepitation (p=0.72), genu varum (p=0.12) or genu varus (p=0.45). None of the knees presented with the almost pathognomonic sign; a painful cord, palpable alongside the medial edge of the patella. A direct trauma to the knee had preceded the symptoms in ten knees (8 patients), including eight with the plica classified on arthroscopy as type C and one classified as a scarred type D. The median duration of symptoms prior to plica resection was 4.5 months (range, 2-72), which did not correlate with the functional outcome scores at the final follow-up (Kujala -0.097, p=0.586; Lysholm 0.0006, p=0.974).

Initial treatment was conservative with rest, physiotherapy, and nonsteroidal anti-inflammatory drugs as needed for all patients. If incapacitating knee pain persisted despite conservative treatment, a thorough arthroscopic examination of the entire knee joint was performed.

5.3.2 Lesion characteristics

In the re-evaluation of the preoperative magnetic resonance images, performed by the two musculoskeletally-oriented radiologists, a medial plica was detected in 21 of the 34 knees. The appearance of the medial plica was, according to the Sakakibara classification, a cordlike elevation in 17 knees (type A, Figure 21; left), shelf-like without covering the anterior surface of the medial condyle in one knee (type B, Figure 21; middle) and large, shelf-like, covering the anterior surface of the medial condyle in three knees (type C, Figure 21; right). No fenestrated plicae (type D) were detected. Thirteen knees were not classified, due to nonidentification of the plica, mostly resulting from the use of fat-suppression sequences and lack of intra-articular fluid or soft-tissue oedema surrounding the plica. The unfavourable sequences also prevented assessment of possible chondral damage or identification of fibrotic plicae from the magnetic resonance images.
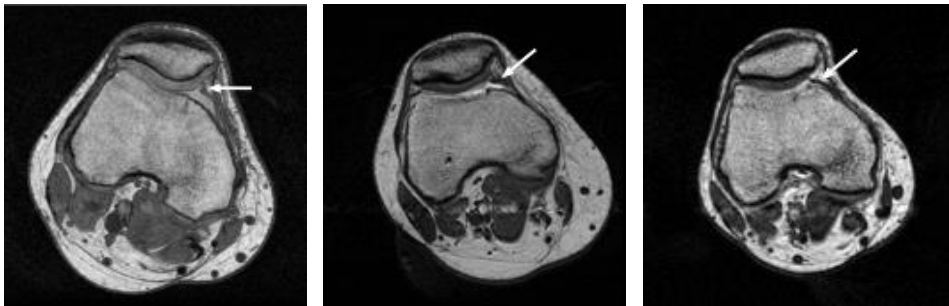

Figure 21. Sakakibara classification (left A, middle B, right C) of medial plicae on axial proton density magnetic resonance images. Reprinted from original publication III (Weckström et al. 2010) with permission of Elsevier.

In the arthroscopic reports, correspondingly, the medial plica was described as small (type A) in 14 knees, moderate (type B) in three, shelf-like (type C, Figure 22) in 16 and fenestrated (type D) in one knee. Four of these plicae were described as fibrotic or having a hard rim, and in the patient who had undergone a previous plica incision 4 years earlier, the plica was described as a tight band of scar tissue (Figure 21; right). In one knee with a fibrotic fairly large plica, an area of 1.5 cm x 1.5 cm of chondral damage could be seen on the responding surface of the medial femoral condyle. One patient had grade 1 chondral changes in the sulcus and patellar area. There were 18 right and 16 left knees operated and 9 patients had bilateral operations.
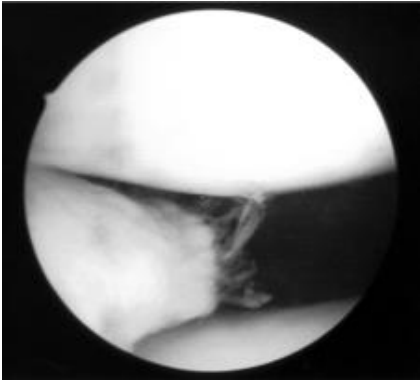
Figure 22. Large shelf-like (type C) medial plica on intraoperative arthroscopic photograph prior to resection. Functional outcome at final follow-up, 4 years after resection, was fair. Reprinted from original publication III (Weckström et al. 2010) with permission of Elsevier.

Arthroscopic observations and magnetic resonance imaging evaluations matched in ten of the 34 knees; most of the matches (8 knees) were type A. Association between the plica size on magnetic resonance images compared to arthroscopic classification was not seen (p=0.74).

5.3.3 Surgery details

If incapacitating knee pain persisted despite conservative treatment, a thorough arthroscopic examination of the entire knee joint was performed. If no other pathology was identified, the medial plica was deemed responsible for the symptoms and resected. The arthroscopic plica resections were performed with either basket forceps or a shaving device. All plicae in this study were arthroscopically resected, not divided. In eight knees, additional synovial tissue bulging into the knee joint was resected (anteromedially or medially around the plica in 6 knees; in the posterior area of the medial compartment in 1 knee; and in the anterolateral area in 1 knee).

5.3.4 Immediate post-operative follow-up and treatment

No postoperative complications were detected during follow-up. All patients were mobilized on the day of surgery or the first postoperative day, and active quadriceps exercises were encouraged. The median length of hospital stay was 3

days (range, 2–5), and the median time for using crutches was 7 days (range, 1–30). Five patients returned to the hospital for a follow-up visit, for others, the postoperative follow-up was done in military garrison outpatient clinics until the patients were fit for normal military training. They returned to work or normal military training after a median of 3 weeks (range, 2–8).

Four patients underwent subsequent arthroscopy before the final follow-up, but neither significant new findings nor a need for re-resection of the medial plica were revealed. Of these patients, two received an arthroscopic intervention, one patient had a resection of the infrapatellar fat pad, and one had a lateral retinacular release. The other two patients had diagnostic arthroscopy but no arthroscopic procedures were deemed necessary. The diagnoses for continued knee problems in these patients were chondral lesion of the femoral condyle in one patient (visible at plica resection), recurrent patellar subluxation in two patients, and in one patient the reason for knee pain remained unclear.

5.3.5 Functional outcome

The long-term follow-up data of the functional results as determined by the Kujala or Lysholm knee scores were excellent to good in 17 patients (68%), fair in five (20%) and poor in three (12%) (Figure 23). The median Kujala score was 92 (range, 25–100), and the median Lysholm score was 89 (range, 26–100). The median visual analogue scale score for knee pain experienced at final follow-up was 1.4 (range, 0–8.8). The functional outcomes measured by either scoring system (Kujala $p = 0.182$, Lysholm $p = 0.391$) or the amount of knee pain at final follow-up ($p = 0.256$) did not correlate with the size of the resected plica.
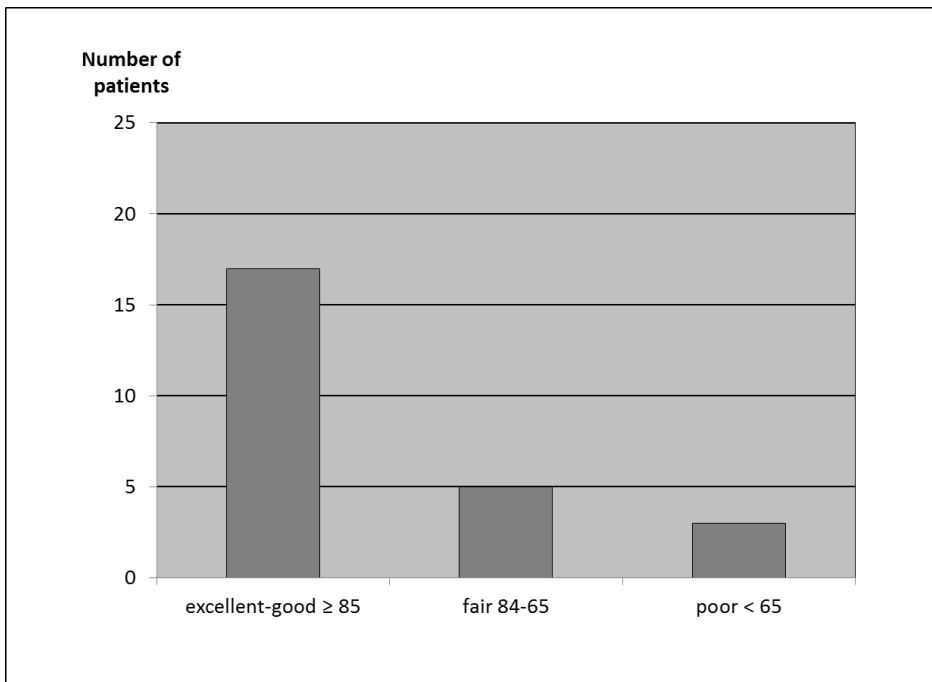
Figure 23. Functional outcome of arthroscopic plica resection as measured by the Kujala score.

5.4   Articular cartilage lesions of the patellae

5.4.1   Clinical symptoms

Only 39% (95% CI: 28%-49%) of the patients with proven articular cartilage lesions of the patellae had typical symptoms and physical findings of anterior knee pain, namely pain after walking stairs and prolonged sitting, and crepitus and pain during active movement of the patella. In 32% symptoms were typical of anterior knee pain, but without findings in clinical examination, and in 28% the only symptom was discomfort and pain in the anterior aspect of the knee without further symptoms or findings. Thirty-one patients (42%) had suffered symptoms of anterior knee pain for less than 1 year, 9 (12%) for 1 to 2 years, and 34 (46%) for more than 2 years.

5.4.2 Surgery details and lesion characteristics

The mean time between magnetic resonance imaging and arthroscopic examination was 3.8 weeks (range, 0-12). All 74 knees were systematically examined on arthroscopy using a probe inserted into the knee joint. Under direct vision and with careful probing, special attention was paid to the patellar surface and the degree of fibrillation, fragmentation, and possible softening of the cartilage surface based on the arthroscopic grading system by Shahriaree. Twenty cases (27%) of the articular cartilage lesions of the patellae based on arthroscopy were grade-I, 32 (43%) were grade-II and 22 (30%) were grade-III. Grade-IV lesions were not found. The grading of articular cartilage lesions of the patellae based on arthroscopy was not associated with the clinical symptoms of anterior knee pain (p=0.61) or the duration of the symptoms before arthroscopy (p=0.75).

5.4.3 Radiology

Plain radiographs of all 74 knees showed normal findings in 70 cases. Lateralization of the patella and a flat sulcus angle (<138 degrees) was found in 3 knees, and Osgood-Schlatter disease was found in 1 knee.

To determine diagnostic sensitivity of 1.0T magnetic resonance imaging, the findings were compared with arthroscopic findings (gold standard). Magnetic resonance imaging scans detected articular cartilage lesions of the patellae in 49 knees, resulting in a sensitivity of 66% (95% CI: 53%-74%). Magnetic resonance imaging scans detected grade I articular cartilage lesions of the patellae with a sensitivity of 20% (95% CI: 8-42%). The higher the grade, the better the detection. Grade II articular cartilage lesions of the patellae were detected with a sensitivity of 72% (95% CI: 55-84%), and grade III articular cartilage lesions of the patellae were always detected on magnetic resonance imaging (sensitivity 100%, 95%CI: 85-100%). Due to the study setting, all patients had articular cartilage lesions of the patellae and thus neither specificity of the diagnostic method nor positive or negative predictive values (PPV, NPV) could be assessed. In 19 knees (26%) magnetic resonance imaging was normal. Diagnoses on magnetic resonance imaging, other than articular cartilage lesions of the patellae, included one medial plica, one medial meniscal tear, and one partial tear in the patellar tendon.

MRI grade*	Arthroscopic grade*			
	I	II	III	Total
0	16	9	0	25
I	3	2	2	7
II	0	19	9	28
III	1	2	9	12
IV	0	0	2	2
Total	20	32	22	74

*Shahriaree (12)

Table 6.   Association of arthroscopic and magnetic resonance imaging grading in 74 knees with articular cartilage lesions of the patellae (study population IV). Reprinted from original publication IV (Mattila et al. 2012) with permission of SAGE Publications.

6 DISCUSSION

6.1 Osteochondritis dissecans (I)

The main finding of study I was that outcomes, both functional results and bone consolidation as seen on magnetic resonance imaging, were statistically significantly better in the group where bioabsorbable nails were used for the fixation, compared to the group where bioabsorbable pins were used. To our knowledge there are no previous studies comparing bioabsorbable pins and nails. Five earlier studies have described the use of bioabsorbable pins in a smaller number of patients (Matsusue et al. 1996, Tuompo et al. 1997, Dervin et al. 1998, Nakagawa et al. 2005). More recent studies report use of bioabsorbable nails, mostly in skeletally immature patients (Din et al. 2006, Abouassaly et al. 2014) or a combination of skeletally immature and mature patients (Millington et al. 2010). In contrast to both earlier and later reports, our study includes a larger number of patients, a longer follow-up, and the use of nails for the fixation of osteochondritis dissecans fragments in skeletally mature knees. Comparing findings of previous reports on bioabsorbable pin or nail fixation is difficult as outcome rating methods have been diverse and most studies have consisted of a mix of skeletally mature and immature patients.

The main difference between the various fixation techniques lies in the rigidity of the fixation. It seems probable that the superior results of nail fixation would be attributable to a more rigid fixation enabled by the barbs and head of the nails in comparison to the smooth surface of the pins. The barbs and head of the nails increase the compression qualities and fixation rigidity, which are important for healing and bone union (Nakagawa et al. 2002). An advantage offered by both fixation devices is the insertion technique; the implant is inserted into the drill hole without any pretapping or tightening being required. This reduces the number of surgical stages as well as the potential risks of improper alignment of bone fragments. In addition, the smaller size of the nail decreases the risk for fracturing the fragment. Wouters et al. have taken this further in an experimental study using meniscus arrows for fixation of osteochondritis dissecans of the knee (Wouters et al. 2011), but no follow-up studies have yet been published.

Complications in the group studied were rare and transient. There was no breakage or other failure of the implants during follow-up. A study by Millington et al. on failure of bioabsorbable nail fixation (Millington et al. 2010) has been cited frequently, but does not paint a very clear picture of the failures observed, and includes a variety of bioabsorbable implants, such as nails, pins, darts and screws. The rate of reoperations reported is similar to the one third in our study. Millington et al. report that two patients treated with bioabsorbable nails had a reoperation due to back-out. Similar numbers of failure have been seen with cannulated metal screw fixation (Edmonds and Polousky 2013), but repeated review articles seem to shun bioabsorbable implants due to risks of complications or breakage (Erickson et al. 2013, Winthrop et al. 2015). On the other hand, a large review reports that fixation with bioabsorbable nails (the implants are referred to as pins, but the device reported is SmartNail) is the most common technique used in treating unstable juvenile osteochondritis dissecans (Abouassaly et al. 2014).

The lesions in this study were large, covering an average of 57% of the condylar joint surface. In 21 knees, i.e. 70%, the lesion area was larger than 300 mm², which on the basis of a previous study has been considered an indication for autologous grafting (Outerbridge et al. 1995) and is similar to the average lesion size reported in studies of newer reconstructive and restorative treatment methods used (Kon et al. 2012). Furthermore, the amount of lesions extending to the weight-bearing area, also known as the "extended classical" lesion, accounted for 60% of our series, thus clearly exceeding the previously reported 6% (Aichroth 1971).

We saw a positive correlation between the size of the lesion and sclerosis on magnetic resonance imaging at follow-up. Several of these patients with sclerosis, i.e. suboptimal healing, of the lesion nevertheless had a good result in terms of outcome. With the results of reconstructive and restorative methods known today, fixation is preferable as a primary treatment option, because it results in better cartilage surface than does chondral reconstruction, and in a majority of cases in good functional outcome (Pascual-Garrido et al. 2009, DiBartola et al. 2016). If fixation fails or is not primarily possible, reconstruction remains a good option. What newer techniques, like biomimetic scaffolds, bone-cartilage paste graft or bone-marrow-derived cell transplantation (Kon et al. 2012, Berruto et al. 2014), will bring into the equation remains to be seen.

The reoperations in the present series might be associated with the large size of the fragment. A reoperation was performed to one-third of our patients, but only two reoperations were attributable to failure of the fixation. In one of the reoperations refixation was performed with bioabsorbable pins, and in the other a

mosaicplasty of the osteochondritis dissecans lesion was performed. Both showed a good outcome at the follow-up. The remaining rearthroscopies reflected the progression of the disease. Previously, a similar trend of progression and further fragmentation has been observed in a long-term follow-up of osteochondritis dissecans treated by internal fixation with metallic pins (Havulinna et al. 1995). It seems possible that the disease might progress regardless of fixation technique once a certain stage has been reached.

Limitations of the present study include a retrospective collection method and a limited amount of patients. Ideally the pin and nail group should have been randomized to avoid selection bias. This was not possible due to the retrospective collection method, where the choice of implant was made by the surgeon according to his preferance. The pin and nail group were, nevertheless, similar in regard to all preoperative characteristics, as no significant statistical differences were seen between the groups. Limited amounts of patients and a retrospective collection method are a frequent problem in studies on treatment of osteochondritis dissecans, as the condition is not common and treatments scattered over several institutions. To meet the need for stronger results in this aspect, The Research in OsteoChondritis of the Knee (ROCK) multi-center study group, has been formed and aspires to perform prospective, comparative research (Edmonds and Polousky 2013, Carey et al. 2016).

A strength of the study is that all the young adult patients had been treated uniformly according to the policy of one institution, without prior selection into pin or nail groups. This was furthermore a homogenous, healthy group of skeletally mature young men, treated for a condition that mostly affects males.

6.2   Bipartite patella (II)

We found an incidence of unresolved painful bipartite patellae of 9.2 per 100,000 conscripts. There is a limited amount of literature on incidence, and it consists mainly of case reports (Halpern and Hewitt 1978, Iossifidis and Brueton 1995, Azarbod et al. 2005). A recent review cites an incidence of bipartite patellae ranging from 0.2 to 6%, with less than 2% being symptomatic (Matic and Flanigan 2014), giving a range of symptomatic bipartite patellae of 4 to 120 per 100,000.

The main finding of study II was that surgical excision of a painful bipartite patella fragment resulted in good to excellent long-term outcome in all but one patient. Post-operative recovery was swift and no major complications were seen.

Over the past three decades, surgical excision of painful bipartite patella has been described in some case reports (Green 1975, Halpern and Hewitt 1978, Ogden et al. 1982), in limited case series including only a few patients (Ishikawa et al. 1994, Ogata 1994), and in two studies of comparable size with the present study; one reported good results for a mixed group of 16 adolescent or adult patients with a follow-up of one year (Weaver 1977), and the other reported on 16 patients aged around 14 years with a 7-year follow-up (Bourne and Bianco 1990). The only previous study focused solely on adults reported favourable outcomes after less than a one-year follow-up for nine patients who underwent excision of a bipartite patella that had become painful following injury to the knee (Iossifidis and Brueton 1995). The last years have seen an addition of two case reports only; a report on arthroscopic excision (referred to in Matic and Flanigan 2015) and one on arthroscopic excision with lateral retinacular release (Felli et al. 2011).

The majority of our patients reported gradual onset of symptoms without specific trauma, and only one third had a more sudden, trauma related onset of symptoms, suggesting the prevailing cause for exacerbation of symptoms was the increased physical exertion level during military service. Preoperative duration of symptoms caused by the painful bipartite patella varied from a few months to several years and was not limited to the military service period. Previous descriptions of painful bipartite patella excision have made a distinction between gradual versus a more sudden onset of symptoms after injury to the knee, and good pain relief was reported for both categories (Green 1975, Weaver 1977, Ogden et al. 1982, Ishikawa et al. 1994, Ogata 1994, Iossifidis and Brueton 1995). Our results seem to support these findings.

Based on our data, painful bipartite patella does not seem primarily associated with anatomic deviations. The radiographic findings indicative of anatomic deviance in this study, with the exception of the bipartite lesion, were rare. A few deviations from normal values were seen with respect to lateralization, tilting, or height of the patella, which could predispose to subluxation and thus to breakage of the interfragmentary fibrotic zone. However, these deviations were few and slight and did not provide grounds for important conclusions. Although the literature dealing with bipartite patella mentions the possibility that anatomic deviations might predispose to bipartite patella becoming painful (van Holsbeek et al. 1987), these parameters have not, to our knowledge, been evaluated in previous studies. The location of the accessory fragment had a similar distribution in our study as in earlier reports where the location was superolateral in 75%, lateral in 20% lateral, and inferior in 5% (Green 1975, Blankstein et al. 2001).

In the 15 year follow-up of our study, the osteoarthritic changes seen were few and unsubstantial, which suggests surgical excision of a symptomatic bipartite fragment does not involve a high risk of osteoarthritis, at least in this time frame. One report speculates that untreated symptomatic bipartite patella might predispose to development of osteoarthritis (Ishikawa et al. 1994). In light of this it might seem possible that removal of an accessory fragment would prevent rather than enhance the long-term predisposition of osteoarthritis. Randomized controlled trials would nevertheless be needed to improve our understanding of the impact of surgical treatment, and the natural course of the condition, respectively, on the outcome.

A limitation to this study was the retrospective collection method for the primary symptom and surgical data, which offered no possibility for tissue samples of the excision area for histologic examination. As the condition is rare, reports on treatment tend to be retrospective case series, which is not an optimal set up.

We nevertheless present a fairly large group of skeletally mature young adults, who underwent uniform treatment according to the policy of one institution. Owing to the compulsory nature of the military service the male conscript patients represent the general, young adult male population of their age group well. Furthermore, this age group is optimal, because it is the age group in which the bipartite patella is most frequently symptomatic and the condition mostly affects males. Our study offers the longest follow-up of excision of bipartite patella in a homogenous patient series consisting entirely of skeletally mature young adults, who differ from skeletally immature adolescents in terms of treatment protocol and healing potential.

6.3   Medial synovial plica (III)

The main finding of study III was that the majority of the young adults had excellent to good functional long-term outcome after arthroscopic resection of medial plica, the only finding considered exceptional in their symptomatic knee in arthroscopy. Pain relief was excellent to good regardless of the size of the plica or duration of symptoms. Previously, excellent to good results have been reported after shorter (3.6 years) follow-up for the majority of 46 resected medial plicae (Hansen and Boe 1989). There are several other studies reporting short-term results consistent with our findings (Vaughan-Lane and Dandy 1982, Nottage et al. 1983, Maffulli et al. 1993, Flanagan et al. 1994, Guney et al. 2010, Schindler 2014)

and others who have included both medial and plicae of other locations in their short term studies (Patel 1978, Hardaker et al. 1980, Dorchak et al. 1991, Johnson et al. 1993, Schindler 2014).

As eight out of our 25 patients had fair to poor results it is probable that the resected plica was not the actual cause of symptoms. Thus arthroscopic resection of plica must be considered carefully and randomized controlled studies are needed to specify the indications for plica resection and to further assess the effectiveness of the procedure.

Half of the resected plicae in our study were small or moderate and half were large or fenestrated, but no correlation could be established between size and final outcome. This is in agreement with previous reports, which note a lack of correlation between the size of the plica and severity of symptoms (Jee et al. 1998, Christoforakis et al. 2006).

Physical findings, with respect to symptomatic medial plicae, were unspecific or absent in preoperative clinical exams. None of the patients presented with the pathognomonic finding of a painful palpable mediopatellar cord, and one third had no finding indicative of a symptomatic medial plica. It seems therefore that the preoperative clinical examination is not a reliable detector of medial plica.

Our study is the first follow-up study with categorical use of magnetic resonance imaging in the preoperative evaluation of patients with symptomatic plicae, aiming to assess the usefulness of magnetic resonance imaging in preoperative diagnostics of this condition. We found poor and non-significant correlation between preoperative magnetic resonance imaging and arthroscopy findings. According to a recent radiological review, a normal plica has low signal on both T1- and T2-weighted images, with possible increased T2 signal intensity seen in symptomatic plicae (Samim et al. 2014). Fat suppression, as well as magnetic resonance arthrography, is considered useful to better delineate the plica when articular fluid is not sufficiently present (Samim et al. 2014, Vassiou et al. 2015). The poor visibility of medial plicae in our patients can be explained partly by the retrospective collection method, and the different preferences and practices among the radiologists in choosing the magnetic resonance imaging protocol for the diverse preoperative diagnoses. It seems crucial that plica specific sequences be used, as sequences producing 'general, all-purpose' images will not necessarily have the visibility needed to detect or evaluate synovial plicae. It should also be kept in mind in clinical diagnostics, that normal magnetic resonance imaging does not exclude medial plica. While the availability of higher, 1.5T and 3.0T, field strength has been expected to result in more accurate assessment of synovial plicae and

possible impingement, the diagnosis of medial plica irritation on magnetic resonance imaging is still considered non-specific (Vassiou et al. 2015). And as limitations to clinical as well as radiological diagnostics persist, arthroscopy remains the gold standard in plica diagnostics.

The retrospective collection method of the study could be considered a limitation in terms of the impact on exactness of the arthroscopic evaluation of the plica size. Another limitation related to the retrospective collection method is that secondary plicae, known to accompany other internal derangements of the knee (Lyu and Hsu 2006, Guney et al. 2010), might have been excluded. Further, the male study population could be considered a limitation in terms of applicability to the general population as the condition affects females as well.

The strengths of this study include the longest follow-up of plica resection ever reported (median 6.6 years) and a relatively good percentage of the patients attending the final follow-up (25 of 33, i.e. 69%).

6.4   Articular cartilage lesions of the patellae (IV)

The main finding of study IV was that sensitivity of 1.0T magnetic resonance imaging for detecting grade I lesions was low and could not be used to confirm the diagnosis or articular cartilage lesions of the patella. For the detection of more severe grade II to III lesions, the magnetic resonance imaging sensitivity was markedly higher. 1.0T magnetic resonance imaging may thus be considered an accurate diagnostic tool for identifying more severe cases of articular cartilage lesions of the patellae.

One recent study reports 76.4% sensitivity of 1.45T magnetic resonance imaging for detection of patellar cartilage lesions (Danieli et al. 2016). A study comparing the use of 1.5T and 3.0T magnetic resonance imaging for the detection of cartilage lesions of the knee reported significantly higher specificity and accuracy with the use of 3.0T, but a sensitivity of 70% for both 1.5T and 3.0T (Kijowski et al. 2009). Previous studies have reported a sensitivity ranging from 57% to 72% with 1.5T magnetic resonance imaging for detecting all grades of articular cartilage lesions of the patellae (McCauley et al. 1992, Lee et al. 2001), the 66% sensitivity of 1.0T magnetic resonance imaging found in our study being within the same range. In addition to higher (1.5T to 3.0T) field strength being available today, new techniques and modalities like T2-mapping, dGEMRIC (delayed gadolinium enhanced magnetic resonance imaging of cartilage), CBCT (delayed cone beam

computer tomography) and 3T MRI with 3D-DESS (three dimensional dual echo in the steady state) are aspiring to further improve imaging of cartilage lesions (Kokkonen et al. 2013, Ruiz Santiago et al. 2014, Kohl et al. 2015). While specialist radiological imaging is specific for cartilage lesions in the knee it still has poorer sensitivity to determine the therapeutic options in this population (Smith et al. 2012). Desirably newer techniques and modalities would enhance our ability to assess the clinical significance of articular cartilage lesions and the relevance of surgical treatment.

A secondary finding of our study was the poor correlation between cartilage lesions identified in arthroscopy and the symptoms of anterior knee pain. This was a somewhat expected finding, because previous literature demonstrates an absence of pathognomonic symptoms (Leslie and Bentley 1978, Grelsamer et al. 2009, Dye 2005). In our sample, only one-third of patients with articular cartilage lesions of the patellae had diffuse anterior knee pain as the sole symptom, while 39% had symptoms of anterior knee pain and patellofemoral crepitus. Our results were even lower than those of a previous study, which showed that 60% of the patients with clinically diagnosed anterior knee pain with retropatellar crepitus had articular cartilage lesions of the patellae (Leslie and Bentley 1978). Based on the findings of the present study, it seems clear that articular cartilage lesions of the patellae cannot be discerned by symptoms and signs in physical examination (Dye 2005). Considering that surgical treatment of articular cartilage lesions of the patellae is required only for a small minority of patients (Dehaven et al. 1979, Duran et al. 2016), and that the effectiveness of surgery is controversial (Federico and Reider 1997, Stoller 2007), arthroscopy is not recommended based solely on suspicion of articular cartilage lesions of the patellae.

A limitation of the present study is the retrospective selection of patients with articular cartilage lesions of the patellae identified by arthroscopy, due to which we were unable to calculate the specificity or positive (PPV) or negative predictive values (NPV) of the diagnostic tests. While the selection method also excluded possible lesions in knees not requiring arthroscopy, it enabled a comparison of magnetic resonance imaging to findings on arthroscopy, still considered gold standard in assessment of chondral lesions of the knee (Smith et al. 2012). The field strength (1.0T) of the magnetic resonance imaging used in our study may be considered a limitation, and a slight improvement of sensitivity is probable with higher (1.5T) field strength being routinely available.

Strengths of the study include a study population consisting of young adults who all had passed their military entry medical examination as healthy. Due to the

compulsory nature of the military service, the study population accurately reflects the young adult male population of our country. Moreover, the age group of our study is optimal, as this is an age frame in which degenerative chondral changes, such as osteoarthritis, do not normally exist. The relatively large group of skeletally mature young adults, that comprised our study population, underwent a uniform general health examination and treatment for anterior knee pain according to the policy of one institution, and standard methods and protocols of the institution were used for the evaluation of clinical symptoms, plain radiographs, magnetic resonance images, and arthroscopy findings.

7 CONCLUSIONS

On the basis of studies I-IV, the following conclusions can be drawn:

I   Arthroscopic fixation with bioabsorbable nails seems to be a suitable method of repair for osteochondritis dissecans of the adult knee, and in our study showed results superior to those of arthroscopic fixation with bioabsorbable pins.

II   Unresolved painful bipartite patella is a rare condition and does not seem primarily associated with anatomic deviations, but when incapacitating pain persists despite nonoperative treatment excellent to good functional outcome, and swift recovery with no apparent tendency of adverse effects in the knee, may be expected after surgical excision. There appears to be no reason to avoid this technically undemanding procedure in the treatment of unresolved bipartite patella in young adults.

III   Good to excellent results in relieving incapacitating knee pain may be expected after arthroscopic resection of the medial plica of the knee . Furthermore, this procedure was not associated with complications or recurrence of symptoms. Preoperative clinical examination and the type of routine magnetic resonance imaging used in the current study seem unreliable in detecting medial plicae. Randomized controlled trials are needed to compare the outcome of the resection of the plicae with the non-operative treatment.

IV   1.0T magnetic resonance imaging may be considered a useful diagnostic tool for identifying more severe cases of articular cartilage lesions of the patellae. In addition, sensitivity of symptoms and physical examination for articular cartilage lesions of the patellae is poor, and diagnosis cannot be based on symptoms alone. Symptoms or findings in clinical examination suspected to be related to articular cartilage lesions of the patellae should not be used as an indication for knee arthroscopy.

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SDG

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